Secure Encrypted Virtualization API Version 0.14

Technical Preview

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Advanced Micro Devices

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Revision History

Date	Revision	Description
October 2017	3.04	• RECEIVE_START works in PSTATE.INIT as well as PSTATE.WORKING. • Updated flowchart to emphasize dependency on PDH_CERT_EXPORT before LAUNCH_START. • Clarification on snapshot constraint. • Other minor edits
August 2017	3.03	• Move Policy to command buffer in all commands • SEND_UPDATE_DATA TRANS_LENGTH parameter is In and Out. • Document MNONCE generation • Insert documentation for RECEIVE_UPDATE_DATA • Removed “Key Management” from title • Many other minor edits
January 2017	3.02	• Split all the *_UPDATE commands into *_UPDATE_DATA and *_UPDATE_VMSA • Added LAUNCH_SECRET command to allow for secret data to be injected into a launched guest. Updated state machine to reflect new command. • Replaced X.509 certificate usage with API-specific formatted certificates. • Added clarity around cryptographic algorithms; Switched from ECC curve P-256 to ECC P-384. • Addressed industry partner inputs to command buffer structures. • General clarifications.
August 2016	3.01	Bug fixes and minor edits.
May 2016	3.00	Initial Release

References

FIPS 186-4	Digital Signature Standard (DSS). Federal Information Processing Standards Publication 186-4. http://nvlpubs.nist.gov/nistpubs/FIPS/NIST.FIPS.186-4.pdf
FIPS 198-1	The Keyed-Hash Message Authentication Code (HMAC). Federal Information Processing Standards Publication 198-1. http://csrc.nist.gov/publications/fips/fips198-1/FIPS-198-1_final.pdf
SP 800-38F	Recommendation for Block Cipher Modes of Operation: Methods for Key Wrapping. NIST Special Publication 800-38F http://nvlpubs.nist.gov/nistpubs/SpecialPublications/NIST.SP.800-38F.pdf
SP 800-56A	Recommendation for Pair-Wise Key Establishment Schemes Using Discrete Logarithm Cryptography. NIST Special Publication 800-56A Revision 2. http://nvlpubs.nist.gov/nistpubs/SpecialPublications/NIST.SP.800-56Ar2.pdf
SP 800-108	Recommendation for Key Derivation Using Pseudorandom Functions. NIST Special Publication 800-108. http://csrc.nist.gov/publications/nistpubs/800-108/sp800-108.pdf
RFC 3279	Algorithms and Identifiers for the Internet X.509 Public Key Infrastructure Certificate and Certificate Revocation List (CRL) Profile. IETF RFC 3279. https://www.ietf.org/rfc/rfc3279.txt
RFC 5480	Elliptic Curve Cryptography Subject Public Key Information. IETF RFC 5480. https://www.ietf.org/rfc/rfc5480.txt
RFC 5758	Internet X.509 Public Key Infrastructure: Additional Algorithms and Identifiers for DSA and ECDSA. IETF RFC 5758. https://www.ietf.org/rfc/rfc5758.txt

Chapter 1 Overview

The Secure Encrypted Virtualization (SEV) feature allows the memory contents of a virtual machine (VM) to be transparently encrypted with a key unique to the guest virtual machine (VM). The memory controller contains a high-performance encryption engine which can be programmed with multiple keys for use by different VMs in the system. The programming and management of these keys and secure data transfer between host hypervisor and guest VM memory is handled by the SEV firmware running AMD Secure Processor. The API available to the host hypervisor for these operations is the focus of this document.

1.1 Operational Model

The capabilities of the SEV feature can support many operational environments. It is capable of supporting both lightweight virtualized containers as well as conventional virtual machines within an enterprise cloud environment. In either case, there are two parties concerned in the deployment of SEV guests: the guest owner and the platform owner. For example, in a cloud environment, the platform owner would be the cloud vendor and the guest owner would be the user that wishes to run their workload in the cloud.

Guest owners wish to protect the confidentiality of the data running within their guests. While they trust the platform owner to provide the infrastructure to run their guest, they benefit from reducing their risk exposure to vulnerabilities within that infrastructure. The SEV feature encrypts the contents of the memory of the guest and provides assurances that it was encrypted properly. The encryption of memory places an additional burden on attackers within the operational environment who may have already obtained some illicit access to the guest's memory through a vulnerability in the hypervisor or other supporting enterprise software.

Platform owners wish to provide such protection to guest owners, but also must manage the computing resources efficiently and effectively. Resource allocation needs to be fluid and their customers data must be safely backed up in case of failure. The SEV feature has been developed to be sensitive to this requirement; it integrates into the conventional guest lifecycle surrounding launching, migration, and snapshotting of guests.

1.2 Platform Management

This section describes the management of the platform by the platform owner.

1.2.1 Platform Lifecycle

The firmware maintains context for the platform. To initialize the platform, the INIT command is executed to initialize and configure the platform context. The INIT command accepts configuration parameters that affect the behavior of the platform until the system is reset or the

SHUTDOWN command is invoked. The SHUTDOWN command clears all platform and guest state that exists in non-persistent storage.

The status of the platform can be queried using the PLATFORM_STATUS command. This command provides information about the state of the platform.

If the platform needs to be reset to factory settings, the PLATFORM_RESET command can be issued by the hypervisor. This command clears all persistently stored platform state including the platform certificates and signing keys (see below).

1.2.2 Identity

The firmware identifies itself by an asymmetric signing key generated during the one-time configuration steps taken before the platform may be put into production. This key is called the Platform Endorsement Key (PEK) and is used to sign the Platform Diffie-Hellman key (PDH). By signing this key, the firmware authenticates the cryptographic contexts built with the PDH.

The firmware provides interfaces to manage the PDH: PDH_GEN and PDH_CERT_EXPORT. The PDH_GEN command generates a new PDH, which is then signed by the PEK. This command is not necessary for normal operation; it is provided to support the ability to generate a fresh PDH in case the platform owner's security policies require it.

The PDH_CERT_EXPORT command exports the PDH and its PEK signature. The PEK is signed by two keys to connect it to two different roots of trust. These roots of trust provide authenticity and ownership proof to third parties, described in the following sections. These signatures are also exported via the PDH_CERT_EXPORT command.

1.2.3 Device Authenticity

The firmware provides a mechanism to verify that it is executing on AMD hardware that is capable of supporting SEV. Each platform contains a chip-unique signing key called the Chip Endorsement Key (CEK). The CEK is signed by the AMD SEV Signing Key (ASK), which is signed by the AMD root signing key (ARK). A guest owner or remote platform interacting with the firmware can obtain the public component of the AMD signing keys to prove the hardware authenticity. The mechanism to obtain the public key is outside the scope of this document.

The CEK signs the PEK. This signature connects the PEK to the ARK, which is a root of trust.

1.2.4 Ownership

The firmware also provides interfaces to verify the identity of the owner of the platform on which it is executing: PEK_CSR and PEK_CERT_IMPORT.

PEK_CSR generates a certificate signing request (CSR) for the PEK. This signing request contains the PEK public key and other identifying information about the platform. When the platform owner's certificate authority is provided this CSR, it generates a certificate using the

public key of the PEK and signs it with its root signing key. This signed certificate connects the PEK to the platform owner's root of trust. It can be used by external parties to verify ownership of the platform.

The platform itself keeps a copy of the PEK certificate in persistent storage. In order to install the certificate in the platform, the PEK_CERT_IMPORT command is issued. Once the certificate is imported, the platform owner has taken ownership of the platform.

1.2.5 Encrypted State

When a #VMEXIT occurs, the register state of the guest is saved to memory in the VMCB save area. Access to this save area exposes the guest register state to manipulation and observation by attackers. To mitigate this, some SEV capable platforms support the AMD SEV Encrypted State (SEV-ES) feature. When enabled, SEV-ES encrypts and integrity protects the VMCB save area with the memory encryption key.

1.3 Guest Lifecycle

The SEV feature supports the common guest lifecycle events so that SEV can integrate well within already existing cloud infrastructures. These events include launching, running, snapshotting, migrating, and decommissioning guests.

The status of a guest is available via the GUEST_STATUS command. This command reports the current SEV state the guest is in and other information.

1.3.1 Launch

When a guest is launched, its memory must first be encrypted before SEV can be enabled in hardware for this guest. The firmware provides interfaces to bootstrap the memory encryption for this purpose: the LAUNCH commands. These six commands together generate a fresh memory encryption key for the guest, encrypt guest memory, and provide an attestation of the successful launch.

LAUNCH_START is called first to create a guest context within the firmware. The hypervisor provides the firmware with the guest's security policy and the public key of the guest owner. The guest policy constrains the use and features activated for the lifetime of the launched guest, such as disallowing debugging, enabling key sharing, or turning on other SEV-related features. The provided public key allows the firmware to establish a cryptographic session with the guest owner to negotiate keys used for attestation (see Chapter 2).

The hypervisor loads the guest into memory and begins calling subsequent LAUNCH_UPDATE_DATA commands.

LAUNCH_UPDATE_DATA encrypts the memory provided to it by the hypervisor. It also calculates a measurement of the memory. This measurement is a signature of the memory contents

that can be sent to the guest owner as an attestation that the memory was encrypted correctly by the firmware.

The hypervisor also initializes the VM save area within the VMCB by issuing LAUNCH_UPDATE_VMSA. This command encrypts the VM save area. The LAUNCH_UPDATE_VMSA command is only used when the SEV-ES feature is enabled.

Once the guest data and VM save areas are encrypted, the hypervisor issues the LAUNCH_MEASURE command to produce a measurement of the data encrypted by the launch flow. The guest owner may wait to provide the guest with confidential information until it can verify the attestation measurement. Since the guest owner knows the initial contents of the guest at boot, the attestation measurement can be verified by comparing it to what the guest owner expects.

To provide the guest with secret data after the measurement is validated, the guest owner wraps a secret and sends it to the guest through the LAUNCH_SECRET command.

After completion of the launch work flow, the hypervisor issues LAUNCH_FINISH to ready the guest for execution.

1.3.2 Activate and Deactivate

AMD-V requires the guest to be associated with an ASID within its VMCB prior to executing a VMRUN instruction to run the guest. Additionally, LAUNCH_UPDATE_DATA and LAUNCH_UPDATE_VMSA require an active ASID. An ASID is an identifier associated with all memory accesses of the guest. SEV uses ASIDs to associate memory encryption keys with the guest. The number of guests that the firmware supports is conceptually unlimited (though resource constraints impose a more practical limit.) However, there are only a limited number of ASIDs that can be simultaneously associated with keys. The firmware provides to the hypervisor interfaces to overcommit ASIDs to guests using the ACTIVATE, DEACTIVATE, and DF_FLUSH commands, and the WBINVD instruction.

The ACTIVATE command allows the hypervisor to inform the firmware that a given guest is associated with an ASID. When this command is issued, the firmware programs the memory controller with the guest's memory encryption key. This key is then associated with the guest's ASID.

The hypervisor uses the DEACTIVATE command to de-allocate an ASID from a guest. This removes the association in the memory controller between the guest and the ASID. A hypervisor may wish to re-allocate this ASID due to operating system specific ASID scheduling protocols. It may also need to re-allocate ASIDs if there are no SEV-capable ASIDs currently available.

Before re-activating an ASID, the firmware requires the hypervisor to flush the cache back to memory with a WBINVD instruction on each core. Once WBINVD completes, the hypervisor must call DF_FLUSH to ensure that the data fabric is completely flushed. The DF_FLUSH command checks that a WBINVD has been executed since the last DEACTIVATE. The firmware enforces the WBINVD and DF_FLUSH flow to ensure any unencrypted data in the cache and data

fabric write buffers associated with the previous key value is written back to memory before the key can be changed. On success, the DF_FLUSH command marks the previously deactivated ASIDs as usable. The DF_FLUSH command provides the hypervisor flexibility to batch multiple DEACTIVATE calls together and flushing the cache and data fabric only once afterwards.

1.3.3 Snapshot and Migrate

Snapshotting and migration both require the memory image of a guest to be removed from the system to be reconstituted at another platform later in time. (Note that in this version of the API, the platform reconstituting the image must be known at the time the snapshot is taken.) To protect the confidentiality of an SEV protected guest while in transit and storage, its memory image must be encrypted with a key that can be recovered by the next platform to execute it. The firmware provides the same set of interfaces to support this protection: SEND_START, SEND_UPDATE_DATA, SEND_UPDATE_VMSA, and SEND_FINISH for the sending or snapshotting platform and RECEIVE_START, RECEIVE_UPDATE_DATA, RECEIVE_UPDATE_VMSA, and RECEIVE_FINISH for the receiving or reconstituting platform.

The SEND_START, SEND_UPDATE_DATA, SEND_UPDATE_VMSA, and SEND_FINISH commands are used to transform the guest's memory image for transmission. SEND_START establishes a cryptographic context with the remote platform. Subsequent invocations of SEND_UPDATE_DATA may be used to encrypt additional memory regions. Each UPDATE operation is independently integrity protected.

The SEND_START command enforces the guest's policy restriction on which platforms it may be transferred to. The policy can require the destination to be an SEV-capable platform or require the receiving platform to have the same owner as the sending one—or both. This check is performed by verifying the receiving platform's platform certificates and certificate chains.

The receiving platform uses the related RECEIVE_START, RECEIVE_UPDATE_DATA, RECEIVE_UPDATE_VMSA, and RECEIVE_FINISH in the same manner as the sending platform. The RECEIVE_START derives the cryptographic context necessary to re-encrypt the guest. The RECEIVE_UPDATE_DATA and RECEIVE_UPDATE_VMSA commands re-encrypts memory regions provided by the hypervisor. The RECEIVE_FINISH command finalizes the operation. However, the RECEIVE_START command does not verify the identity of the sending platform.

The RECEIVE_START command is the only command other than the LAUNCH_START command that generates a new guest context and guest handle.

1.3.4 Decommission

When the hypervisor needs to shut down a guest, it issues the DECOMMISSION command to the firmware. The firmware then deletes the memory encryption key and all other internal state the firmware has kept for the guest.

1.3.5 Debugging

The firmware provides two interfaces to assist in the debugging of an SEV enabled guest: DBG_ENCRYPT and DBG_DECRYPT. These commands request the firmware to encrypt or decrypt the data at the given memory regions provided by the hypervisor. Since decrypting protected memory allows the hypervisor to gain access to guest memory, the guest policy must explicitly allow debugging to enable these two commands.

Chapter 2 Key Management

The primary purpose of the firmware is to manage the memory encryption keys and the keys to support the guest lifecycle within an enterprise environment. This section describes each of these keys. Table 1 summarizes all the keys, their abbreviations, their algorithm, and their usage.

Table 1. Summary of Keys

Key	Abbr.	Algorithm	Usage
Platform Diffie-Hellman Key	PDH	ECDH curve P-384	Key agreement
Platform Endorsement Key	PEK	ECDSA curve P-384	Signing the PDH
Chip Endorsement Key	CEK	ECDSA curve P-384	Signing the PEK
AMD SEV Signing Key	ASK	RSA 2048	Signing the CEK
AMD Root Key	ARK	RSA 2048	Signing the ASK; AMD root of trust
Owner Certificate Authority	OCA	ECDSA curve P-384	Signing the PEK; platform owner root of trust
Transport Integrity Key	TIK	HMAC SHA-256	Trusted channel Integrity
Transport Encryption Key	TEK	AES 128	Trusted channel confidentiality
Key Encryption Key	KEK	AES 128	Key wrapping
Key Integrity Key	KIK	HMAC SHA-256	Key wrapping
VM Encryption Key	VEK	AES 128	Guest memory encryption

2.1 Keys

This section describes the management of the platform by the platform owner.

2.1.1 Platform Diffie-Hellman Key

The Platform Diffie-Hellman key (PDH) is an Elliptic Curve Diffie Hellman (ECDH) key using curve P-384 as defined in section D.1.2.3 of [FIPS 186-4]. The PDH is used to negotiate a master secret between the SEV firmware and external entities. This master secret is then used with a key derivation function (KDF) to establish a trusted channel.

The SEV firmware generates the PDH using output from a secure entropy source. The lifetime of this key is the lifetime of the platform's membership in its cloud or domain. When the Platform Encryption Key (PEK) changes, the PDH is regenerated.

2.1.2 Platform Endorsement Key

The Platform Endorsement Key (PEK) is an ECDSA signing key using curve P-384 as defined in section D.1.2.3 of [FIPS 186-4] It signs the PDH to anchor the PDH to the AMD root of trust and the platform owner's root of trust.

The SEV firmware generates the PEK using a secure entropy source. The lifetime of this key is the lifetime of the platform's membership in its cloud or domain.

2.1.3 Chip Endorsement Key

The Chip Endorsement Key (CEK) is an ECDSA signing key using curve P-384 as defined in section D.1.2.3 of [FIPS 186-4]. It signs the PEK to anchor the PEK to the AMD root of trust. Each chip has a unique CEK which is derived from secrets stored in chip-unique OTP fuses. The lifetime of this key is the lifetime of the individual chip.

2.1.4 AMD Signing Key

The AMD SEV Signing Key (ASK) is an RSA 2048-bit key pair. It is an intermediate signing key, signed by the ARK. The ASK private key signs the CEK public key to demonstrate that the CEK is an authentic AMD key.

The AMD Key Distribution Server (KDS) managed by AMD contains the ASK private key. The lifetime of this key is the lifetime of the product line.

2.1.5 Owner Certificate Authority Signing Key

The platform owner's Certificate Authority key (OCA) is an ECDSA signing key using curve P-384 as defined in section D.1.2.3 of [FIPS 186-4]. It is the root of trust of the platform owner and its signatures signify platform ownership. The OCA private key signs the PEK public key to demonstrate that the PEK is owned by the platform owner.

When the platform is self-owned, the firmware stores both the OCA private key and public key. In this case, no entity outside of the SEV firmware has access to the OCA private key; the SEV firmware generates the OCA key pair using a secure entropy source.

When the platform is owned by an external entity, the firmware stores only the OCA public key. In this case, only the platform owner has access to the private key; the platform owner must generate the OCA key pair according to its own security policies.

When the SEV firmware stores anything, including the OCA certificate, in non-volatile storage, it is encrypted and integrity protected.

2.1.6 AMD Root Key

The AMD Root key (ARK) is an RSA 2048 key pair. It is the root of trust of AMD and its signatures signify AMD authenticity. The ARK private key signs the ASK public key to demonstrate that the ASK is an authentic AMD key.

The AMD KDS that is managed by AMD contains the ARK private key. The lifetime of this key is the lifetime of the product line.

2.1.7 Transport Integrity Key

The Transport Integrity Key (TIK) is an HMAC SHA-256 integrity key. The SEV firmware uses the TIK to integrity protect all trusted information transferred between the firmware and external entities such as the guest owner or another SEV firmware instance.

The SEV firmware generates the TIK during the sending operational flows. In this case, the firmware generates the TIK from a secure entropy source.

The SEV firmware imports a wrapped TIK during the launching and receiving operational flows.

The lifetime of this key is the lifetime of a single send, receive, or launch session. Once SEND_FINISH, RECEIVE_FINISH, or LAUNCH_FINISH are invoked respectively, the TIK is destroyed.

2.1.8 Transport Encryption Key

The Transport Encryption Key (TEK) is an AES-128 encryption key. The SEV firmware uses the TEK to encrypt all confidential information transferred between the firmware and external entities such as the guest owner or another SEV firmware instance.

The SEV firmware generates the TEK during the sending operational flows. In this case, the firmware generates the TEK from a secure entropy source.

The SEV firmware imports a wrapped TEK during the launching and receiving operational flows.

The lifetime of this key is the lifetime of a single send, receive, or launch session. Once SEND_FINISH, RECEIVE_FINISH, or LAUNCH_FINISH are invoked respectively, the TEK is destroyed.

2.1.9 Key Encryption Key

The Key Encryption Key (KEK) is an AES-128 encryption key. It is used to wrap the TEK and TIK during session establishment.

The SEV firmware derives the KEK from the master secret negotiated during the key agreement protocol. The lifetime of this key is the lifetime of a single send, receive, or launch session. Once

SEND_FINISH, RECEIVE_FINISH, or LAUNCH_FINISH are invoked respectively, the KEK is destroyed.

2.1.10 Key Integrity Key

The Key Integrity Key (KIK) is an HMAC-SHA-256 key. It is used to wrap the TEK and TIK during session establishment.

The SEV firmware derives the KIK from the master secret negotiated during the key agreement protocol. The lifetime of this key is the lifetime of a single send, receive, or launch session. Once SEND_FINISH, RECEIVE_FINISH, or LAUNCH_FINISH are invoked respectively, the KIK is destroyed.

2.1.11 VM Encryption Key

The VM Encryption Key (VEK) is an AES-128 encryption key. The UMC uses the memory encryption key to encrypt guest data while the guest is operating.

The SEV firmware generates the memory encryption key from a secure entropy source. The lifetime of this key is the lifetime of the guest while it executes on this platform. The guest will use a different VEK when migrated to a remote platform. The remote platform is responsible for generation of the new VEK.

2.2 Usage

The SEV firmware must be capable of communicating securely with other parties. This section describes how the firmware establishes a trusted channel between itself and the remote party.

Each trusted channel has a client and server. In the SEV API, the guest owner and the SEV firmware instance issuing send commands are designated the client parties. The SEV firmware issuing launch and receive commands are designated the servers. These designations do not imply any further semantics beyond this trusted channel protocol.

2.2.1 Key Derivation Function

The SEV firmware uses a key derivation function (KDF) to securely derive new secrets from old secrets. Specifically, it uses the KDF to derive the CEK from fused secrets, to derive transport keys from a negotiated master secret, and to derive the MNONCE used in LAUNCH_MEASURE. The KDF used is the counter mode KDF specified in NIST [SP 800-108], Section 5.1. It uses the HMAC-SHA-256 as the underlying pseudorandom function (PRF). The parameter r is set to 32 and the length in bits of [L]¬2 is 32.

2.2.2 Master Secret Derivation

Key agreement is accomplished using the Elliptic Curve Diffie-Hellman (ECDH) protocol. The protocol follows the Static Unified Model described in Section 6.3.2 of NIST [SP 800-56A].

In summary, the following occurs:

- The client retrieves the server's ECDH public key, Q¬¬S
- The client transmits its ECDH public key, QC, to the server
- The client transmits a fresh nonce, N, to the server
- The client calculates a shared secret, Z, from Q¬¬S and its private key, dC.
- The server calculates a shared secret, Z, from Q¬¬C and its private key, dS.
- The client and server calculate the master secret, M, from Z and N using the KDF.

The derivation of M uses the KDF. The parameters to the KDF are:

- Secret input: Z
- Label: "sev-master-secret", ASCII encoded (17 bytes).
- Context: N

The intermediate secret Z must be securely deleted after the master secret is derived.

2.2.3 Transport Key Establishment

The client generates the transport encryption key (TEK) and the transport integrity key (TIK). The TEK and TIK are then transmitted to the server using key wrapping keys derived from the master secret, M.

The Key Encryption Key (KEK) is derived using the KDF with the following parameters:

- Secret input: M
- Label: "sev-kek", ASCII encoded (7 bytes).
- Context: None

The Key Integrity Key (KIK) is derived using the KDF with the following parameters:

- Secret input: M
- Label: "sev-kik", ASCII encoded (7 bytes).
- Context: None

The TEK and TIK are concatenated together in that order, encrypted, and integrity protected using the scheme specified in Section 2.2 on page 25, using the KEK as the encryption key, the KIK as the integrity key, and a freshly generated IV.

When transmitting guest data from client to server, the TEK and TIK are used with the data protection scheme specified in Section 2.2 on page 25, according to the command specification.

2.2.4 Data Protection

The SEV API uses a common data protection scheme for multiple uses. The data protection scheme requires the following input parameters:

- A 128-bit initialization vector, IV
- A 128-bit encryption key, K
- A 128-bit integrity protection key, I
- A message to protect, M

Two different messages should never be protected with the same IV and K. The IV may be repeated only when used with a different K.

The data protection scheme used by this API utilizes AES-128 CTR mode for confidentiality protection and HMAC-SHA-256 for integrity protection. The output of this data protection is:

- C = AES-128-CTR(M; K, IV)
- MAC = HMAC-SHA-256(C; I)

The client must send C, MAC, and IV to the server to allow the server to recover the plaintext.

Chapter 3 Guest Policy

The firmware maintains a guest policy provided by the guest owner. This policy is enforced by the firmware and restricts what configuration and operational commands can be performed on this guest by the hypervisor. The policy also requires a minimum firmware level.

The guest policy is provided to firmware during guest launch. The policy is then bound to the guest and cannot be changed throughout the lifetime of the guest. The policy is also transmitted during snapshot and migration flows and enforced on the destination platform.

The guest policy is a 4-byte structure with the fields shown in Table 2:

Table 2. Guest Policy Structure

Offset	Bit(s)	Name	Description
000h	0	NODBG	Debugging of the guest is disallowed when set
	1	NOKS	Sharing keys with other guests is disallowed when set
	2	ES	SEV-ES is required when set
	3	NOSEND	Sending the guest to another platform is disallowed when set
	4	DOMAIN	The guest must not be transmitted to another platform that is not in the domain when set.
	5	SEV	The guest must not be transmitted to another platform that is not SEV capable when set.
	15:6	Reserved. Should be zero.	
002h	7:0	API_MAJOR	The guest must not be transmitted to another platform with a lower firmware version.
003h	7:0	API_MINOR	

The policy bits for a given guest are referenced with the format POLICY.<FLAG_NAME>. For instance, the key sharing flag is referred to as POLICY.NOKS.

Chapter 4 Mailbox Register Protocol

Software on the x86 CPUs communicate with the AMD Secure Processor through a set of MMIO registers, referred to as mailbox registers. This section describes the protocol used by the x86 SEV driver for communicating through these mailbox registers in order to invoke the SEV key management functions described in this API.

In a nutshell, the driver writes the command ID and 64-bit physical address of a command buffer (if parameters are required) into the mailbox registers. The SEV firmware takes action and returns a 16-bit return code and potentially writes output to the same physical address parameter region.

4.1 Mailboxes

The SEV API exposes an external interface to the x86 system software through three memory mapped registers: CmdResp, CmdBufAddr_Hi, and CmdBufAddr_Lo. Their formats are described in Table 3, Table 4, and Table 5 respectively.

Table 3. CmdResp Register Layout

Bit#	Description/Purpose
31	0: Command; 1: Response
[30:26]	Reserved. Must be zero.
[25:16]	Command ID
[15:0]	When bit 31 is 1: Status code from SEV Firmware When bit 31 is 0: Bit 0: x86 requests SEV FW to interrupt on completion. Other bits are reserved, must be zero.

Table 4. CmdBufAddr_Hi Register Layout

Bit#	Description/Purpose
31:0	Most significant 32 bits of the physical address of the command buffer

Table 5. CmdBufAddr_Lo Register Layout

Bit#	Description/Purpose
31:0	Least significant 32 bits of the physical address of the command buffer

The x86 system software issues commands to the firmware by writing to these registers. The x86 system software first constructs a command buffer (formatted specifically for the given command) within system DRAM. The x86 system software then writes the most significant 32 bits of the command buffer's physical address into the CmdBufAddr_Hi register and the least significant 32 bits into the CmdBufAddr_Lo address.

The x86 software then writes to the CmdResp register to issue the command with bit 31 set to 0 to indicate that this an issued command and bits [25:16] containing the command identifier. The

values written into bits [15:1] are reserved and must be written as 0 by the x86 software. The x86 software may set bit 0 to inform the SEV firmware to interrupt the x86 core upon command completion.

Upon command completion, the PSP firmware writes to the CmdResp register. The PSP firmware sets bit 31 to 1 to indicate that this is a command response and bits [15:0] to the 16-bit status code.

If the command is not recognized, an INVALID_COMMAND status code is returned.

4.2 Command Buffer

The x86 system software is responsible for allocating the command buffer. The size of the command buffer is fixed for a given command. Some commands require the command buffer to be populated with pointers to secondary buffers. The x86 system software is also responsible for allocating these secondary buffers.

The command buffer and all secondary buffers must reside within memory accessible to the x86 system software. The SEV API enforces this by checking the validity of all pointers provided by the x86 system software before use.

All pointers provided by the x86 software are 64-bit system physical addresses.

4.3 Command Identifiers

Table 6 summarizes the platform management, guest management, and debugging commands. See the command definitions for further details.

Table 6. Command Identifiers

Command	ID	Description
INIT	001h	Initialize the platform
SHUTDOWN	002h	Shut down the platform
PLATFORM_RESET	003h	Delete the persistent platform state
PLATFORM_STATUS	004h	Return status of the platform
PEK_GEN	005h	Generate a new PEK
PEK_CSR	006h	Generate a PEK certificate signing request
PEK_CERT_IMPORT	007h	Import the signed PEK certificate
PDH_CERT_EXPORT	008h	Export the PDH and its certificate chains
PDH_GEN	009h	Generate a new PDH and PEK signature
LAUNCH_START	030h	Begin to launch a new SEV enabled guest
LAUNCH_UPDATE_DATA	031h	Encrypt guest data for launch
LAUNCH_UPDATE_VMSA	032h	Encrypt guest VMCB save area for launch
LAUNCH_MEASURE	033h	Output the launch measurement
LAUNCH_UPDATE_SECRET	034h	Import a guest secret sent from the guest owner

Table 6. Command Identifiers (Continued)

Command	ID	Description
LAUNCH_FINISH	035h	Complete launch of guest
SEND_START	040h	Begin to send guest to new remote platform
SEND_UPDATE_DATA	041h	Re-encrypt guest data for transmission
SEND_UPDATE_VMSA	042h	Re-encrypt guest VMCB save area for transmission
SEND_FINISH	043h	Complete sending guest to remote platform
RECEIVE_START	050h	Begin to receive guest from remote platform
RECEIVE_UPDATE_DATA	051h	Re-encrypt guest data from transmission
RECEIVE_UPDATE_VMSA	052h	Re-encrypt guest VMCB save area from transmission
RECEIVE_FINISH	053h	Complete receiving guest from remote platform
GUEST_STATUS	023h	Query the status and metadata of a guest
ACTIVATE	021h	Load a guest's key into the memory controller
DEACTIVATE	022h	Unload a guest's key into the memory controller
DF_FLUSH	00Ah	Flush the data fabric
DECOMMISSION	020h	Delete the guest's SEV context in firmware
DBG_DECRYPT	060h	Decrypt guest memory region for debugging
DBG_ENCRYPT	061h	Encrypt guest memory region for debugging

4.4 Status Codes

Table 7 summarizes the status codes that can be returned by the firmware commands. See the command definitions for further details.

Table 7. Status Codes

Status	Code	Description
SUCCESS	0x0000	Successful completion
INVALID_PLATFORM_STATE	0x0001	The platform state is invalid for this command
INVALID_GUEST_STATE	0x0002	The guest state is invalid for this command
INVALID_CONFIG	0x0003	The platform configuration is invalid
INVALID_LENGTH	0x0004	A memory buffer is too small.
ALREADY_OWNED	0x0005	The platform is already owned
INVALID_CERTIFICATE	0x0006	The certificate is invalid
POLICY_FAILURE	0x0007	Request is not allowed by guest policy

Status	Code	Description
INACTIVE	0x0008	The guest is inactive
INVALID_ADDRESS	0x0009	The address provided is invalid
BAD_SIGNATURE	0x000A	The provided signature is invalid
BAD_MEASUREMENT	0x000B	The provided measurement is invalid
ASID_OWNED	0x000C	The ASID is already owned
INVALID_ASID	0x000D	The ASID is invalid
WBINVD_REQUIRED	0x000E	WBINVD instruction required
DFFLUSH_REQUIRED	0x000F	DF_FLUSH invocation required
INVALID_GUEST	0x0010	The guest handle is invalid
INVALID_COMMAND	0x0011	The command issued is invalid.
ACTIVE	0x0012	The guest is active.
HWERROR_PLATFORM	0x0013	A hardware condition has occurred affecting the platform. It is safe to re-allocate parameter buffers.
HWERROR_UNSAFE	0x0014	A hardware condition has occurred affecting the platform. It is not safe to re-allocate parameter buffers.
UNSUPPORTED	0x0015	Feature is unsupported.
INVALID_PARAM	0x0016	A parameter is invalid.

4.5 Endianness

All integral values passed between the firmware and the CPU driver are little-endian formatted unless otherwise specified. That is, the first byte of the integer representation is the least significant byte. Note that this applies to all bit integer values in public keys and signatures unless explicitly stated otherwise.

4.6 Synchrony

The SEV API processes commands serially. The x86 system software receives a response when the SEV firmware has completed processing the command. The x86 system software must not send subsequent commands before receiving a response from the SEV firmware for the first sent command.

Any subsequent commands sent by the x86 system software before receiving a response must be ignored by the SEV firmware and must not result in any change to the platform or any guest context.

4.7 Address Validation

All addresses provided by x86 system software are checked by SEV firmware to ensure that the regions do not overlap invalid memory regions. Each address is checked that it does not have any of the following properties:

- Bits 46:43 != 0
- Overlaps TSseg
- Overlaps ASeg
- Is above the max physical address (7FD_0000_0000)
- Lies within any Trusted Memory Region (TMR) that disallows x86 software access

This check is performed before any action is taken on the contents of addresses provided by the x86 system software as parameters. If the check fails, an INVALID_ADDRESS status code is returned.

Chapter 5 Platform Management API

This chapter describes the platform management commands. Platform management commands are used by the platform owner to provision the platform and query platform-wide data.

5.1 Overview

This section overviews the platform management and provides the background to understand the semantics of each command.

5.1.1 Platform Context

The SEV firmware maintains a platform context throughout the lifetime of the platform. This context contains data and metadata necessary to implement the SEV API.

Table 8. Platform Context (PCTX) Fields

Field	Field Description
STATE	The current state of the platform in the PSTATE finite state machine.
CONFIG	The configuration of the platform.
PDH	Platform Diffie Hellman key.
PEK	Platform Endorsement Key.
CEK	Chip Endorsement Key.
OCA	Owner Certificate Authority key.
GUEST_COUNT	Number of guest contexts currently managed by the firmware.
GUESTS	The guest contexts currently managed by the firmware.

The platform context is denoted PCTX. The PCTX fields are referenced as PCTX.<FIELD>. For instance, the number of guests currently managed by the platform would be denoted PCTX.GUEST_COUNT. When unambiguous, the PCTX portion may be omitted.

5.1.2 Platform State Machine

The SEV firmware traverses a platform finite state machine during operation. The firmware may only execute certain commands in each platform state. Guest commands are only valid in INIT and WORKING platform states.

Table 9. PSTATE Finite State Machine

State	Value	Description	Allowed Platform Commands
UNINIT	0h	The platform is uninitialized.	INIT, PLATFORM_RESET, PLATFORM_STATUS
INIT	1h	The platform is initialized but not currently managing any guests.	SHUTDOWN, PLATFORM_STATUS, PEK_GEN, PEK_CSR, PEK_CERT_IMPORT, PDH_GEN, PDH_CERT_EXPORT, DF_FLUSH
WORKING	2h	The platform is initialized and current managing guests.	SHUTDOWN, PLATFORM_STATUS, PDH_GEN, PDH_CERT_EXPORT, DF_FLUSH

The platform finite state machine is denoted PSTATE. The PSTATE states are referenced as PSTATE.<STATE>. For instance, the uninitialized state is denoted PSTATE.UNINIT.

5.1.3 Authenticity

An authentic platform is a platform that is executing AMD developed firmware on AMD hardware. Authenticity allows the guest owner to trust that the platform it communicates with will implement SEV correctly and securely.

The authenticity of the platform is defined by a certificate chain rooted in the ARK, the AMD root of trust. The ARK signs the ASK, which in turn signs the CEK. The CEK signs the PEK which roots the PEK in the AMD root of trust, asserting that this platform is an authentic AMD platform.

5.1.4 Ownership

A platform may be owned by an external entity or it may be self-owned. Platforms can disallow migration of guests to platforms that do not share the same owner. This allows platform owners to contain guests within a known set of servers.

The platform ownership is defined by a certificate chain rooted in the OCA, the owner's root of trust. The OCA signs the PEK. When the platform is not owned by an external entity, the platform generates its own OCA key pair.

5.1.5 Non-volatile Storage

The platform stores identity information in non-volatile storage available to the firmware. The identity information includes the following:

- PDH key pair
- PDH certificate
- PEK key pair
- PEK certificate
- OCA public key
- OCA private key (only if self-owned)
- OCA certificate

The firmware writes each of these keys immediately after generation, derivation, or import. The persistent data is stored encrypted and integrity protected.

If a power failure occurs during a write operation to non-volatile storage, the persistent data may become corrupted. Upon executing the INIT command immediately after the power failure, the command will return an integrity check failure status code. In such a case, the platform must be reset with the PLATFORM_RESET command.

5.1.6 Power State Transitions

Table 10 summarizes the effects of power state transitions on the firmware.

Table 10. Power Management Transitions

Power State	Effect
S0, S1, S2, S3	The firmware volatile state is not affected and resumes execution after transitioning out of the low power states.
Hybrid Sleep	This is equivalent to preparing to transition to S4, but transitioning to S3. If a power failure occurs, the system resumes as if it transitioned to S4. If not, it the system resumes as if it transitioned to S3.
S4, S5, Mechanical Off	The firmware starts from the reset state and must be re-initialized. No non-persistent state is recovered from the point before the power state transition.

5.1.7 SEV-ES Trusted Memory Region

The SEV-ES product feature requires that the x86 system software donate a 1 MB region aligned on a 1 MB boundary to the firmware for exclusive use by the firmware during the lifetime of the platform (until a SHUTDOWN command invocation). The firmware uses the memory region to store integrity data necessary to support the SEV-ES functionality. Attempts by the x86 to access this memory while donated will result in exceptions that frequently cause system instability.

5.2 INIT

This command is used by the platform owner to the initialize the platform. This command loads the SEV related persistent data from non-volatile storage and initializes the platform context. In typical workflows, this command should be the first command issued, aside from the possible invocation of PLATFORM_STATUS to determine the supported API version.

5.2.1 Actions

The platform must be in the PSTATE.UNINIT state.

The firmware first loads the persistent state into its private memory, and then performs the following actions:

- The CEK is derived from the chip unique values.
- If no OCA certificate exists, a OCA signing key is generated and a self-signed OCA certificate is created. The signing key and certificate are written to persistent storage.
- If no PEK exists or the OCA was just regenerated, a PEK signing key is generated and a PEK certificate is created and signed by the OCA and CEK. The PEK and its certificate are written to persistent storage.
- If no PDH exists or the PEK was just regenerated, a PDH key is generated. A certificate is created for the PDH and is signed by the PEK.
- All SEV-related ASIDs on all cores are marked invalid. Each core requires a WBINVD before activating any guest. See ACTIVATE and DEACTIVATE for further details.

Upon successful completion, the platform transitions to the PSTATE.INIT state.

5.2.2 Parameters

Table 11 specifies the parameters for the INIT command.

Table 11. INIT Command Buffer

Byte Offset	Bits	In / Out	Name	Description
00h	0	In	–	SEV-ES is initialized for the platform when set. It is disabled for all guests when not set.
	31:1	–	–	Reserved. Must be zero.
04h	31:0	–	–	Reserved. Must be zero.
08h	63:0	In	TMR_PADDR	If CONFIG.ES=1, system physical address to memory region donated by hypervisor for SEV-ES operations. Must be 1MB aligned. Ignored if CONFIG.ES=0
10h	31:0	In	TMR_LENGTH	If CONFIG.ES=1, length of the memory region

				donated by hypervisor for SEV-ES operation. Must equal 1MB. Ignored if CONFIG.ES=0

5.2.3 Status Codes

Table 12 enumerates the possible status codes returned by this command.

Table 12. INIT Command Status Codes

Return Value	Reason
SUCCESS	Successful completion
INVALID_PARAM	A parameter is invalid
INVALID_PLATFORM_STATE	The platform is not in the PSTATE.UNINIT state
INVALID_LENGTH	A buffer length is not correct
INVALID_CONFIG	The configuration flags are invalid or unsupported
INVALID_ADDRESS	A memory region provided contains invalid physical addresses.
HWERROR_PLATFORM	A hardware condition has occurred affecting the platform. It is safe to re-allocate parameter buffers.
HWERROR_UNSAFE	A hardware condition has occurred affecting the platform. It is unsafe to re-allocate parameter buffers.

5.3 SHUTDOWN

The SHUTDOWN command is used by the platform owner to transition the platform to the uninitialized state.

5.3.1 Actions

The platform may be in any state.

All platform and guest state maintained by the firmware is securely deleted from volatile storage.

If SEV-ES is enabled during platform initialization, the firmware returns control of the SEV-ES TMR back to the x86. After this command completes, the TMR will be accessible by x86 software.

Upon successful completion, the platform transitions to the PSTATE.UNINIT state.

5.3.2 Parameters

None. CmdBuf_Lo and CmdBuf_Hi registers are ignored.

5.3.3 Status Codes

Table 13 enumerates the possible status codes returned by this command.

Table 13. SHUTDOWN Command Status Codes

Return Value	Reason
SUCCESS	Successful completion
HWERROR_PLATFORM	A hardware condition has occurred affecting the platform. It is safe to re-allocate parameter buffers.
HWERROR_UNSAFE	A hardware condition has occurred affecting the platform. It is unsafe to re-allocate parameter buffers.

5.4 PLATFORM_RESET

The PLATFORM_RESET command is used by the platform owner to reset the non-volatile SEV related data. Invoking this command is useful when the owner wishes to transfer the platform to a new owner or securely dispose of the system.

5.4.1 Actions

The platform must be in the PSTATE.UNINIT state. Otherwise, an error is returned.

The persistent state is securely deleted from non-volatile storage.

The platform remains in the PSTATE.UNINIT state after completion.

5.4.2 Parameters

None. CmdBuf_Lo and CmdBuf_Hi registers are ignored.

5.4.3 Status Codes

Table 14 enumerates the possible status codes returned by the PLATFORM_RESET command.

Table 14. PLATFORM_RESET Command Status Codes

Return Value	Reason
SUCCESS	Successful completion.
INVALID_PLATFORM_STATE	The platform is not in the PSTATE.UNINIT state.
HWERROR_PLATFORM	A hardware condition has occurred affecting the platform. It is safe to re-allocate parameter buffers.
HWERROR_UNSAFE	A hardware condition has occurred affecting the platform. It is unsafe to re-allocate parameter buffers.

5.5 PLATFORM_STATUS

The PLATFORM_STATUS command is used by the platform owner to collect the current status of the platform.

5.5.1 Actions

The platform may be in any state.

If the platform is in the PSTATE.UNINIT state, then the following fields are set to zero:

- OWNER
- CONFIG.ES
- GUEST_COUNT

The OWNER bit is set to 1 if the platform is owned by an external owner. The OWNER bit is set to 0 if the platform is self-owned.

The CONFIG flags are equal to the values passed to the INIT command.

The platform remains in the same state after completion.

5.5.2 Parameters

Table 15 specifies the parameters for the PLATFORM_STATUS command.

Table 15. PLATFORM_STATUS Command Buffer

Byte Offset	Bits	In / Out	Name	Description
00h	7:0	Out	API_MAJOR	Major API version
01h	7:0	Out	API_MINOR	Minor API version
02h	7:0	Out	STATE	Current platform state. See Table 3.
03h	0	Out	OWNER	OWNER=0: Self-owned OWNER=1: Externally owned.
	7:1	–	–	Reserved. Set to zero.
04h	0	Out	CONFIG.ES	SEV-ES is initialized for the platform when set. It is disabled for all guests when not set.
	23:1	–	–	Reserved. Set to zero.
	31:24	Out	BUILD	Firmware Build ID for this API version.
08h	31:0	Out	GUEST_COUNT	Number of valid guests maintained by the firmware

5.5.3 Status Codes

Table 16 enumerates the possible status codes returned by the PLATFORM_STATUS command.

Table 16. PLATFORM_STATUS Command Status Codes

Return Value	Reason
SUCCESS	Successful completion
INVALID_ADDRESS	A memory region provided contains invalid physical addresses

5.6 PEK_GEN

This command is used to generate a new PEK. This may be used to regenerate the identity of the platform if required by the user's policy. This command is not necessary for normal workflows as the INIT command regenerates this after being invoked for the first time after a platform reset.

5.6.1 Actions

The platform must be in the PSTATE.INIT state. Otherwise, an error is returned.

The following objects are securely deleted from volatile and non-volatile storage:

- PEK key pair
- PEK certificate
- PDH key pair
- PDH certificate
- OCA key pair (if the platform is self-owned)
- OCA certificate

A new OCA signing key pair and self-signed certificate are generated and stored in non-volatile storage. The previous OCA certificate (and signing key if self-owned) is securely deleted.

A new PEK signing key pair and certificate signed by the new OCA are generated and stored in non-volatile storage. The previous PEK signing key and certificate are securely deleted.

A new PDH key pair is generated and signed by the PEK. Regeneration of the PDH is equivalent to the invocation of the PDH_GEN command.

Note that in this version of the API, this command is an alias for an invocation of SHUTDOWN, PLATFORM_RESET, and INIT, in that order.

The platform remains in the same state after completion.

5.6.2 Parameters

None. The CmdBuf_Lo and CmdBuf_Hi mailbox registers are ignored.

5.6.3 Status Codes

Table 17 enumerates the possible status codes returned by the PEK_GEN command.

Table 17. PEK_GEN Command Status Codes

Return Value	Reason
SUCCESS	Successful completion
INVALID_PLATFORM_STATE	The platform is not in the PSTATE.INIT state
HWERROR_PLATFORM	A hardware condition has occurred affecting the platform. It is safe to re-allocate parameter buffers
HWERROR_UNSAFE	A hardware condition has occurred affecting the platform. It is unsafe to re-allocate parameter buffers.

5.7 PEK_CSR

During the provisioning process, the owner of the platform can take ownership using this command in conjunction with the PEK_CERT_IMPORT command. The CSR contains identifying information of this platform and also contains the PEK public key. A certificate authority processes the CSR by generating a certificate with the information from the CSR and signing it with its key.

The caller can issue this command with the PEK_CSR_LEN field set to zero to query the correct amount of memory to allocate for the CSR.

5.7.1 Actions

The platform must be in the PSTATE.INIT or PSTATE.WORKING states. Otherwise, an error is returned.

A CSR is generated which contains the PEK public key to be signed. The CSR format is identical to the SEV certificate with zero signatures. See Appendix C on page 92 for the certificate format.

If the PEK_CSR_LEN is too small, the required length is written out to that field and an error is returned. Otherwise, the number of bytes written to the buffer are written into PEK_CSR_LEN.

The platform remains in the same state after completion.

5.7.2 Parameters

Table 18 specifies the parameters for the PEK_CSR command.

Table 18. PEK_CSR Command Buffer

Byte Offset	Bits	In / Out	Name	Description
00h	63:0	In	PEK_CSR_PADDR	System physical address of the region to output the PEK certificate signing request. See Appendix C for layout.
08h	31:0	In, Out	PEK_CSR_LEN	Length of the region to output the PEK certificate signing request in bytes.

5.7.3 Status Codes

Table 19 enumerates the possible status codes returned by the PEK_CSR command.

Table 19. PEK_CSR Command Status Codes

Return Value	Reason
SUCCESS	Successful completion.
INVALID_LENGTH	A length field is invalid.
INVALID_PLATFORM_STATE	The platform is not in the PSTATE.INIT or PSTATE.WORKING states.
INVALID_ADDRESS	A memory region provided contains invalid physical addresses.
HWERROR_PLATFORM	A hardware condition has occurred affecting the platform. It is safe to re-allocate parameter buffers.
HWERROR_UNSAFE	A hardware condition has occurred affecting the platform. It is unsafe to re-allocate parameter buffers.

5.8 PEK_CERT_IMPORT

During the provisioning process, the platform can be joined to a domain using this command in conjunction with the PEK_CSR command. The CSR contains the identifying information of this platform and the PEK public key. A certificate authority processes the CSR by generating a certificate with the information from the CSR and signing it with its key. This command imports the certificate of the PEK and OCA into the platform.

Note that this provisioning process should be performed by the platform owner in a trusted environment. In an untrusted environment—particularly where the x86 software is untrusted—this request could be intercepted and replaced with a certificate chain crafted by the attacker.

5.8.1 Actions

The platform must be in the PSTATE.INIT state. Otherwise, an error is returned.

The platform must be self-owned. This requirement ensures that the caller has regenerated the PEK via PEK_GEN and therefore PEKs will never be shared by owners.

The OCA and PEK certificates are validated. Validation involves the following steps:

- The algorithms of the PEK and OCA must be supported
- The version of the PEK and OCA certificates must be supported
- The PEK certificate must match the current PEK
- The OCA signature on the PEK certificate must be valid

The OCA certificate and PEK signature are then written into the platform context as well as to non-volatile storage.

The PDH is regenerated and signed with the new PEK. This action is equivalent to the PDH_GEN command.

The platform remains in the same state after completion.

5.8.2 Parameters

Table 20 specifies the parameters for the PEK_CERT_IMPORT command.

Table 20. PEK_CERT_IMPORT Command Buffer

Byte Offset	Bits	In / Out	Name	Description
00h	63:0	In	PEK_CERT_PADDR	System physical address of the region containing the PEK certificate. See Appendix C for layout.
08h	31:0	In	PEK_CERT_LEN	Length of the region containing the PEK certificate, in bytes.
0Ch	31:0	—	—	Reserved. Must be zero.
10h	63:0	In	OCA_CERT_PADDR	System physical address of the region containing the OCA certificate. See Appendix C.
18h	31:0	In	OCA_CERT_LEN	First certificate in the chain. Signed by CERT2. Length of the region containing the OCA certificate, in bytes.

5.8.3 Status Codes

Table 21 enumerates the possible status codes returned by the PEK_CERT_IMPORT command.

Table 21. PEK_CERT_IMPORT Command Status Codes

Return Value	Reason
SUCCESS	Successful completion.
INVALID_PLATFORM_STATE	The platform is not in the PSTATE.INIT states.
INVALID_LENGTH	A buffer length is not correct.
ALREADY_OWNED	The platform is already owned.
INVALID_CERTIFICATE	A provided certificate is invalid or the PEK does not match the current PEK.
INVALID_ADDRESS	A memory region provided contains invalid physical addresses.
HWERROR_PLATFORM	A hardware condition has occurred affecting the platform. It is safe to re-allocate parameter buffers.
HWERROR_UNSAFE	A hardware condition has occurred affecting the platform. It is

	unsafe to re-allocate parameter buffers.

5.9 PDH_GEN

This command may be used to re-generate the PDH as often as desired. Note that if other entities are using the current PDH to establish keys to encrypt data or provide integrity checking, regenerating the PDH will invalidate any ongoing key establishment work. In this case, the other entities must retrieve the new PDH in order to perform key establishment.

5.9.1 Actions

The platform must be in the PSTATE.INIT or PSTATE.WORKING states. Otherwise, an error is returned.

The PDH key pair is regenerated. The PDH certificate is created and signed by the PEK. The current PDH key pair and certificate are replaced with the new PDH key pair and certificate.

The platform remains in the same state after completion.

5.9.2 Parameters

None. The CmdBuf_Lo and CmdBuf_Hi mailbox registers are ignored.

5.9.3 Status Codes

Table 22 enumerates the possible status codes returned by the PHD_GEN command.

Table 22. PDH_GEN Command Status Codes

Return Value	Reason
SUCCESS	Successful completion.
INVALID_PLATFORM_STATE	The platform must be in the PSTATE.INIT or PSTATE.WORKING states.
HWERROR_PLATFORM	A hardware condition has occurred affecting the platform. It is safe to re-allocate parameter buffers.
HWERROR_UNSAFE	A hardware condition has occurred affecting the platform. It is unsafe to re-allocate parameter buffers.

5.10 PDH_CERT_EXPORT

This command is used to to retrieve the PDH and identity of the platform. This information may then be exported to remote entities which wish to establish a secure transport context with the platform in order to transmit data securely.

5.10.1 Actions

The platform must be in the PSTATE.INIT or PSTATE.WORKING states. Otherwise, an error is returned.

Exports the following data that can be used by an external party to authenticate the identity of the platform and establish keys:

- The PDH certificate
- The CEK certificate
- The PEK certificate
- The OCA certificate
- If the PDH_CERT_LEN or CERT_LEN fields are too small, the required length is written out to those fields and an error is returned. Otherwise, the number of bytes written to the buffers are written into PDH_CERT_LEN and CERT_LEN, respectively.

The platform remains be in the same state after completion.

5.10.2 Parameters

Table 23 and Table 24 specify the parameters for the PDH_CERT_EXPORT command.

Table 23. PDH_CERT_EXPORT Command Buffer

Byte Offset	Bits	In / Out	Name	Description
00h	63:0	In	PDH_CERT_PADDR	System physical address of the region containing the PDH certificate. See Appendix C for layout.
08h	31:0	In, Out	PDH_CERT_LEN	Length of the region containing the PDH certificate, in bytes.
0Ch	31:0	—	—	Reserved. Must be zero.
10h	63:0	In	CERTS_PADDR	System physical address of the region containing the PDH certificate chain. See Table 24 for the layout.
18h	31:0	In, Out	CERTS_LEN	Length of the region containing the PDH certificate chain, in bytes.

Table 24. PDH_CERT_EXPORT Certificates Buffer

Byte Offset		Bits	In / Out	Name	Description
0000h – 0823h		—	Out	PEK_CERT	The PEK certificate. See Appendix C for layout.
0824h – 1047h		—	Out	OCA_CERT	The OCA certificate. See Appendix C for layout.
1048h – 186Bh		—	Out	CEK_CERT	The CEK certificate. See Appendix C for layout.

5.10.3 Status Codes

Table 25 enumerates the possible status codes returned by the PDH_CERT_EXPORT command.

Table 25. PDH_CERT_EXPORT Command Status Codes

Return Value	Reason
SUCCESS	Successful completion.
INVALID_LENGTH	A buffer length is not correct.
INVALID_PLATFORM_STATE	The platform is not in the PSTATE.INIT or PSTATE.WORKING states.
INVALID_ADDRESS	A memory region provided contains invalid physical addresses.
HWERROR_PLATFORM	A hardware condition has occurred affecting the platform. It is safe to re-allocate parameter buffers.
HWERROR_UNSAFE	A hardware condition has occurred affecting the platform. It is unsafe to re-allocate parameter buffers.

Chapter 6 Guest Management API

This chapter describes the management of guest contexts throughout the guest lifecycle.

6.1 Overview

This chapter describes the SEV context of an SEV-enabled guest.

6.1.1 Guest Context

The SEV firmware maintains guest contexts throughout the lifetime of the platform. The guest context contains data and metadata necessary to implement the SEV API specific to a guest.

Table 26. Guest Context (GCTX) Fields

Field	Field Description
STATE	The current state of this guest in the GSTATE finite state machine
HANDLE	The handle of this guest
ASID	The ASID currently associate with this guest.
ACTIVE	Flag describing whether this guest is currently active
POLICY	This guest's policy
VEK	The memory encryption key of the guest
NONCE	The trusted channel nonce currently associated with this guest
MS	The master secret current associated with this guest
TEK	The transport encryption key currently associated with this guest
TIK	The transport integrity key currently associated with this guest
LD	The launch digest context for this guest

A guest context is denoted GCTX. The GCTX fields are referenced as GCTX.<FIELD>. The GCTX prefix is omitted if it's unnecessary in context.

Table 27. GSTATE Finite State Machine

State	Value	Description	Allowed Guest Commands
UNINIT	0h	The guest is uninitialized.	LAUNCH_START, RECEIVE_START
LUPDATE	1h	The guest is currently being launched and plaintext data and VMCB save areas are being imported.	LAUNCH_UPDATE_DATA, LAUNCH_UPDATE_VMSA, LAUNCH_MEASURE, ACTIVATE, DEACTIVATE, DECOMMISSION, GUEST_STATUS

Table 27. GSTATE Finite State Machine (Continued)

State	Value	Description	Allowed Guest Commands
LSECRET	2h	The guest is currently being launched and ciphertext data are being imported.	LAUNCH_SECRET, LAUNCH_FINISH, ACTIVATE, DEACTIVATE, DECOMMISSION, GUEST_STATUS
RUNNING	3h	The guest is fully launched or migrated in, and not being migrated out to another machine.	ACTIVATE, DEACTIVATE, DECOMMISSION, SEND_START, GUEST_STATUS
SUPDATE	4h	The guest is currently being migrated out to another machine.	SEND_UPDATE_DATA, SEND_UPDATE_VMSA, SEND_FINISH, ACTIVATE, DEACTIVATE, DECOMMISSION, GUEST_STATUS
RUPDATE	5h	The guest is currently being migrated from another machine.	RECEIVE_UPDATE_DATA, RECEIVE_UPDATE_VMSA, RECEIVE_FINISH, ACTIVATE, DEACTIVATE, DECOMMISSION, GUEST_STATUS

Each SEV guest managed by the SEV firmware traverses a finite state machine during operation. The firmware will only execute certain commands in each guest state.

The guest finite state machine is denoted GSTATE. The GSTATE states are referenced as GSTATE.<STATE>. For instance, the uninitialized state is denoted GSTATE.UNINIT.

6.1.2 Activation and Deactivation

The number of ASIDs that can be associated with a VEK and used with SEV are limited. The limit is implementation specific and can be retrieved via CPUID Fn8000_001F[ECX]. To allow for the execution of a larger number of guests, the SEV firmware provides the ability to activate and deactivate guests.

6.2 LAUNCH_START

This command is used to bootstrap a guest by encrypting its memory with a new VEK. This command creates a guest context managed by the SEV firmware which can then be referred to by the handle passed out to the caller.

6.2.1 Actions

A new guest context is created and assigned to an available guest handle.

If the HANDLE field is zero, a new VEK is generated for this guest. If the HANDLE field is non-zero, the following checks are performed:

- HANDLE is a valid guest
- GUESTS[HANDLE].POLICY is equal to the POLICY field
- POLICY.NOKS is zero

If the above checks pass, then the VEK from the guest referred to by HANDLE is copied into the new guest context.

The handle of the new guest is written to the HANDLE field.

The launch digest stored in GCTX.LD field is initialized.

If POLICY.ES is set and the platform is configured with SEV-ES, then SEV-ES is enabled. If POLICY.ES is set and the platform is not configured with SEV-ES, an error is returned. Otherwise, SEV-ES is disabled.

A version check is performed to ensure that the API version implemented on the platform provides the proper functionality requested by the initiator of the guest VM. The major API version of this platform must be greater than the guest's POLICY.API_MAJOR field value, or the major API version is equal to POLICY.API_MAJOR, and the minor API version of this platform is greater than or equal to POLICY.API_MINOR. If all of these conditions are not met then an error is returned.

If DH_CERT_PADDR is equal to 0h, then the DH_CERT_LEN, SESSION_PADDR, and SESSION_LEN fields are ignored. The subsequent launch commands will use 0h for both the TEK and TIK.

After successful completion of this command, the guest is transitioned to the GSTATE.LUPDATE state.

The platform transitions to the PSTATE.WORKING state.

6.2.2 Parameters

Table 28 and Table 29 specify the parameters for the LAUNCH_START command.

Table 28. LAUNCH_START Command Buffer

Byte Offset	Bits	In / Out	Name	Description
00h	31:0	In, Out	HANDLE	Guest handle.
04h	31:0	In	POLICY	Guest policy.
08h	63:0	In	DH_CERT_PADDR	System physical address of the region containing the guest owner DH certificate. See Appendix C for the layout.
10h	31:0	In	DH_CERT_LEN	Length of the region containing the guest owner DH certificate, in bytes.
14h	31:0	–	–	Reserved. Must be zero.
18h	63:0	In	SESSION_PADDR	System physical address of the region containing the session parameters.
20h	31:0	In	SESSION_LEN	Length of the region containing the session parameters, in bytes.

Table 29. LAUNCH_START Session Data Buffer

Byte Offset	Bits	In / Out	Name	Description
00h	127:0	In	NONCE	Session nonce.
10h	255:0	In	WRAP_TK	Encrypted TEK and TIK.
30h	127:0	In	WRAP_IV	IV for key wrap.
40h	255:0	In	WRAP_MAC	MAC for key wrap.
60h	255:0	In	POLICY_MAC	Guest policy MAC.

6.2.3 Status Codes

Table 30 enumerates the possible status codes returned by the LAUNCH_START command.

Table 30. LAUNCH_START Status Codes

Return Value	Reason
SUCCESS	Successful completion.
INVALID_PLATFORM_STATE	The platform is not in the PSTATE.INIT or PSTATE.WORKING states.
INVALID_LENGTH	A buffer length is not correct.
INVALID_GUEST	The guest handle is invalid.
POLICY_FAILURE	The guest policy was violated.

Table 30. LAUNCH_START Status Codes (Continued)

Return Value	Reason
BAD_MEASUREMENT	Failed to verify the integrity of a field covered by a MAC.
INVALID_ADDRESS	A memory region provided contains invalid physical addresses.
UNSUPPORTED	SEV-ES has not been configured.
HWERROR_PLATFORM	A hardware condition has occurred affecting the platform. It is safe to re-allocate parameter buffers.
HWERROR_UNSAFE	A hardware condition has occurred affecting the platform. It is unsafe to re-allocate parameter buffers.

6.3 LAUNCH_UPDATE_DATA

This command is used to encrypt guest data with its VEK.

6.3.1 Actions

The platform must be in the PSTATE.WORKING state.

The guest must be in the GSTATE.LUPDATE state. The guest must be activated with an ASID using the ACTIVATE command.

The GCTX.LD is updated with the plaintext contents of the memory region pointed to by PADDR. The plaintext context is then encrypted with the guest's VEK in place.

The platform remains in the same state after completion.

The guest remains in the same state after completion.

6.3.2 Parameters

Table 31 specifies the parameters for the LAUNCH_UPDATE_DATA command.

Table 31. LAUNCH_UPDATE_DATA Command Buffer

Byte Offset	Bits	In / Out	Name	Description
00h	31:0	In	HANDLE	Guest handle
04h	31:0	-	-	Reserved. Must be zero.
08h	63:0	In	PADDR	System physical address of the data to be encrypted. Must be 16 B aligned.
10h	31:0	In	LENGTH	Length of the data to be encrypted. Must be a multiple of 16 B.

6.3.3 Status Codes

Table 32 enumerates the possible status codes returned by the LAUNCH_UPDATE_DATA command.

Table 32. LAUNCH_UPDATE_DATA Status Codes

Return Value	Reason
SUCCESS	Successful completion.
INVALID_PLATFORM_STATE	The platform is not in the PSTATE.WORKING state.
INVALID_LENGTH	A buffer length is not correct.
INVALID_GUEST_STATE	The guest state is not in the GSTATE.LUPDATE state.
INVALID_GUEST	The guest handle is invalid.
INACTIVE	The guest is inactive.
INVALID_ADDRESS	A memory region provided contains invalid physical addresses.
HWERROR_PLATFORM	A hardware condition has occurred affecting the platform. It is safe to re-allocate parameter buffers.
HWERROR_UNSAFE	A hardware condition has occurred affecting the platform. It is unsafe to re-allocate parameter buffers.

6.4 LAUNCH_UPDATE_VMSA

This command is used to encrypt the guest VMCB save area with its VEK. This command is only allowed when SEV-ES is enabled for this guest and when SEV-ES is configured for the platform.

6.4.1 Actions

The platform must be in the PSTATE.WORKING state.

The guest must be in the GSTATE.LUPDATE state. The guest must be activated with an ASID using the ACTIVATE command.

The GCTX.LD is updated with the plaintext contents of the VMCB save area pointed to by PADDR. The VMCB save area is prepared for SEV-ES usage and is then encrypted with the guest's VEK in place.

The platform remains in the same state after completion.

The guest remains in the same state after completion.

6.4.2 Parameters

Table 33 specifies the parameters for the LAUNCH_UPDATE_VMSA command.

Table 33. LAUNCH_UPDATE_VMSA Command Buffer

Byte Offset	Bits	In / Out	Name	Description
00h	31:0	In	HANDLE	Guest handle.
04h	31:0	-	-	Reserved. Must be zero.
08h	63:0	In	PADDR	System physical address of the data to be encrypted. Must be 16 B aligned.
10h	31:0	In	LENGTH	Length of the data to be encrypted. Must be 4096 B.

6.4.3 Status Codes

Table 34 enumerates the possible status codes returned by the LAUNCH_UPDATE_VMSA command

Table 34. LAUNCH_UPDATE_VMSA Status Codes

Return Value	Reason
SUCCESS	Successful completion.
INVALID_PLATFORM_STATE	The platform is not in the PSTATE.WORKING state.
INVALID_LENGTH	A buffer length is not correct
INVALID_GUEST_STATE	The guest state is not in the GSTATE.LUPDATE state.
INVALID_GUEST	The guest handle is invalid.
INACTIVE	The guest is inactive.
INVALID_ADDRESS	A memory region provided contains invalid physical addresses.
UNSUPPORTED	SEV-ES has not been configured.
HWERROR_PLATFORM	A hardware condition has occurred affecting the platform. It is safe to re-allocate parameter buffers.
HWERROR_UNSAFE	A hardware condition has occurred affecting the platform. It is unsafe to re-allocate parameter buffers.

6.5 LAUNCH_MEASURE

This command returns the measurement of the launched guest's memory pages and VMCB save areas (if ES is enabled). The measurement is keyed with the TIK so the guest owner can use the measurement to verify that the guest was properly launched without tampering.

6.5.1 Actions

The platform must be in the PSTATE.WORKING state.

The guest must be in the GSTATE.LUPDATE state.

If the MEASURE_LEN is too small, the required length is written out to that field and an error is returned. Otherwise, the number of bytes written to the buffer are written into MEASURE_LEN.

GCTX.LD is finalized, producing the hash digest of all plaintext data imported into the guest. A nonce is derived and written into the MNONCE field. The MNONCE value is derived using the KDF based on the master secret (see 2.2.1), the ASCII label "sev-mnonce" (10-bytes), and no context.

The launch measurement is calculated as:

HMAC(GCTX.POLICY || GCTX.LD || MNONCE; GCTX.TIK)

where “||” represents concatenation. The launch measurement is written into the MEASURE field.

The platform remains in the same state after completion.

The guest transitions to the GSTATE.LSECRET state.

6.5.2 Parameters

Table 35 and Table 36 specify the parameters for the LAUNCH_MEASURE command.

Table 35. LAUNCH_MEASURE Command Buffer

Byte Offset	Bits	In / Out	Name	Description
00h	31:0	In	HANDLE	Guest handle
04h	31:0	-	-	Reserved. Must be zero.
08h	63:0	In	MEASURE_PADDR	System physical address of the region containing the launch measurement. See Table 36 for layout.
10h	31:0	In, Out	MEASURE_LEN	Length of the region containing the launch measurement, in bytes.

Table 36. LAUNCH_MEASURE Measurement Buffer

Byte Offset	Bits	In / Out	Name	Description
00h	255:0	Out	MEASURE	Measurement of the launched guest
20h	127:0	Out	MNONCE	Nonce used in the measurement

6.5.3 Status Codes

Table 37 enumerates the possible status codes returned by the LAUNCH_MEASURE command.

Table 37. LAUNCH_MEASURE Status Codes

Return Value	Reason
SUCCESS	Successful completion
INVALID_PLATFORM_STATE	The platform is not in the PSTATE.WORKING state
INVALID_LENGTH	A buffer length is not correct.
INVALID_GUEST_STATE	The guest state is not in the GSTATE.LUPDATE state
INVALID_GUEST	The guest handle is invalid
INVALID_ADDRESS	A memory region provided contains invalid physical addresses
HWERROR_PLATFORM	A hardware condition has occurred affecting the platform. It is safe to re-allocate parameter buffers.
HWERROR_UNSAFE	A hardware condition has occurred affecting the platform. It is unsafe to re-allocate parameter buffers.

6.6 LAUNCH_SECRET

This command is used by the guest owner to inject a secret into the guest. This can be done after the launch measurement is retrieved and verified by the guest owner.

6.6.1 Actions

The platform must be in the PSTATE.WORKING state.

The guest must be in the GSTATE.LSECRET state.

Before all other processing, the MAC field is verified. The MAC is calculated as follows:

HMAC(0x01 || FLAGS || IV || GUEST_LENGTH || TRANS_LENGTH || DATA; GCTX.TIK)

Where "||" represents concatenation, FLAGS is the full 32-bit FLAGS field, and DATA is ciphertext pointed to by TRANS_PADDR.

The data pointed to by TRANS_PADDR is decrypted with GCTX.TEK. If FLAGS.COMPRESSED is set to 1, then the resulting plaintext is then decompressed. The result is then written to GUEST_PADDR, encrypted with the guest's VEK.

The platform remains in the same state after completion.

The guest remains in the same state after completion.

6.6.2 Parameters

Table 38 and Table 39 specify the parameters for the LAUNCH_SECRET command.

Table 38. LAUNCH_SECRET Command Buffer

Byte Offset	Bits	In / Out	Name	Description
00h	31:0	In	HANDLE	Guest handle.
04h	31:0	-	-	Reserved. Must be zero.
08h	63:0	In	HDR_PADDR	System physical address of the region containing the packet header. See Table 39 for the layout.
10h	31:0	In	HDR_LEN	Length of the region containing the packet header in bytes.
14h	31:0	-	-	Reserved. Must be zero.
18h	63:0	In	GUEST_PADDR	System physical of the guest memory region. Must be 16 B aligned.
20h	31:0	In	GUEST_LENGTH	Length of guest memory region. Must be a multiple of 16 B and no more than 16 kB.
24h	31:0	-	-	
28h	63:0	In	TRANS_PADDR	System physical address of the transport memory buffer.
30h	31:0	In	TRANS_LENGTH	Length of the transport memory buffer.

Table 39. LAUNCH_SECRET Packet Header Buffer

Byte Offset	Bits	In / Out	Name	Description
00h	0	In	FLAGS.COMPRESSED	If set, data is compressed.
	31:1	-	-	Reserved. Must be zero.
04h	127:0	In	IV	Initialization vector.
14h	255:0	In	MAC	Integrity protection MAC.

6.6.3 Status Codes

Table 40 enumerates the possible status codes returned by the LAUNCH_SECRET command

Table 40. LAUNCH_SECRET Status Codes

Return Value	Reason
SUCCESS	Successful completion.
INVALID_PLATFORM_STATE	The platform is not in the PSTATE.WORKING state.
INVALID_LENGTH	A buffer length is not correct.
INVALID_GUEST_STATE	The guest state is not in the GSTATE.LSECRET state.
INVALID_PARAM	A parameter is invalid.
INVALID_GUEST	The guest handle is invalid.
INACTIVE	The guest is inactive.
INVALID_ADDRESS	A memory region provided contains invalid physical addresses.
BAD_MEASUREMENT	The measurement of the secret is invalid.
HWERROR_PLATFORM	A hardware condition has occurred affecting the platform. It is safe to re-allocate parameter buffers.
HWERROR_UNSAFE	A hardware condition has occurred affecting the platform. It is unsafe to re-allocate parameter buffers.

6.7 LAUNCH_FINISH

After the launch flow is completed, this command is used to transition the guest into a state ready to be run.

6.7.1 Actions

The platform must be in the PSTATE.WORKING state.

The guest must be in the GSTATE.LSECRET state.

The following fields of the guest context are zeroed:

- GCTX.TEK
- GCTX.TIK
- GCTX.MS
- GCTX.NONCE
- GCTX.LD

The platform remains in the same state after completion.

The guest transitions to the GSTATE.RUNNING state.

6.7.2 Parameters

Table 41 specifies the parameters for the LAUNCH_FINISH command.

Table 41. LAUNCH_FINISH Command Buffer

Byte Offset	Bits	In / Out	Name	Description
00h	31:0	In	HANDLE	Guest handle.

6.7.3 Status Codes

Table 42 enumerates the possible status codes returned by the LAUNCH_FINISH command.

Table 42. LAUNCH_FINISH Status Codes

Return Value	Reason
SUCCESS	Successful completion.
INVALID_PLATFORM_STATE	The platform is not in the PSTATE.WORKING state.
INVALID_GUEST_STATE	The guest state is not in the GSTATE.LSECRET state.
INVALID_GUEST	The guest handle is invalid.
INVALID_ADDRESS	A memory region provided contains invalid physical addresses.
HWERROR_PLATFORM	A hardware condition has occurred affecting the platform. It is safe to re-allocate parameter buffers.
HWERROR_UNSAFE	A hardware condition has occurred affecting the platform. It is unsafe to re-allocate parameter buffers.

6.8 SEND_START

This command is used to export a guest from one platform to another. It can be used for saving a guest to disk to be resumed later, or it can be used to migrate a guest across the network to a receiving platform.

6.8.1 Actions

The platform must be in the PSTATE.WORKING state.

The guest must be in the GSTATE.RUNNING state.

GCTX.POLICY.NOSEND must be zero. Otherwise, an error is returned.

If GCTX.POLICY.SEV is 1, the PDH, PEK, CEK, ASK, and ARK certificates are validated.

A version check is performed to ensure that the API version implemented on the receiving platform provides the proper functionality requested by the initiator of the guest. The receiving platform API version is read from the PEK certificate. The major API version of the receiving platform must be greater than the guest's POLICY.API_MAJOR field value, or the major API version is equal to POLICY.API_MAJOR, and the minor API version of the receiving platform is greater than or equal to POLICY.API_MINOR. If all of these conditions are not met then an error is returned.

If GCTX.POLICY.SEV is 0, this certificate chain is ignored and no version check is performed.

If GCTX.POLICY.DOMAIN is 1, the PDH-PEK-OCA are validated. If GCTX.POLICY.DOMAIN is 0, this certificate chain is ignored.

When required by the guest policy, the PDH, PEK, OCA, and CEK certificates are validated according to Appendix C on page 92. The ASK and ARK certificates are validated according to Appendix B on page 90.

A fresh nonce is generated and written into the NONCE field. The master secret is calculated with NONCE and PDH_CERT fields and the PCTX.PDH private key according to the key establishment protocol specified in Chapter 2 on page 22. Fresh TEK and TIK transport keys are generated. The transport keys are then wrapped according to Chapter 2 on page 22, and the output is placed in the WRAP_TK, WRAP_IV, and WRAP_MAC fields.

GCTX.POLICY is written to the POLICY field and a MAC of GCTX.POLICY is calculated, keyed with TIK. The MAC is written to the POLICY_MAC field.

The platform remains in the same state after completion.

The guest transitions to the GSTATE.SUPDATE state.

6.8.2 Parameters

Table 43, Table 44, Table 45 and Table 46 specify the parameters for the SEND_START command.

Table 43. SEND_START Command Buffer

Byte Offset	Bits	In / Out	Name	Description
00h	31:0	In	HANDLE	Guest handle.
04h	31:0	Out	POLICY	Guest policy
08h	63:0	In	PDH_CERT_PADDR	System physical address of the region containing the PDH certificate. See Appendix C for the layout.

Table 43. SEND_START Command Buffer (Continued)

Byte Offset	Bits	In / Out	Name	Description
10h	31:0	In	PDH_CERT_LEN	Length of the region containing the PDH certificate in bytes.
14h	-	-	-	Reserved. Must be zero.
18h	63:0	In	PLAT_CERTS_PADDR	System physical address of the region containing the platform certificates. See Table 44 for the layout.
20h	31:0	In	PLAT_CERTS_LEN	Length of the region containing the platform certificate in bytes.
24h	-	-	-	Reserved. Must be zero.
28h	63:0	In	AMD_CERTS_PADDR	System physical address of the region containing the AMD certificates. See Table 45 for the layout.
30h	31:0	In	AMD_CERTS_LEN	Length of the region containing the AMD certificates in bytes.
34h	-	-	-	Reserved. Must be zero.
38h	63:0	In	SESSION_PADDR	System physical address of the region containing the session data. Table 46 for the layout.
40h	31:0	In, Out	SESSION_LEN	Length of the region containing the session data in bytes.

Table 44. SEND_START Platform Certificates Buffer

Byte Offset	Bits	In / Out	Name	Description
0000h – 0823h	-	In	PEK_CERT	The PEK certificate. See Appendix C for the layout.
0824h – 1047h	-	In	OCA_CERT	The OCA certificate. See Appendix C for the layout.
1048h – 186Bh	-	In	CEK_CERT	The CEK certificate. See Appendix C for the layout.

Table 45. SEND_START AMD Certificates Buffer

Byte Offset	Bits	In / Out	Name	Description
Variable	-	In	ASK_CERT	The ASK certificate. See Appendix B for the layout.
Variable	-	In	ARK_CERT	The ARK certificate. See Appendix B for the layout.

Table 46. SEND_START Session Data Buffer

Byte Offset	Bits	In / Out	Name	Description
00h	127:0	Out	NONCE	Session nonce.
10h	255:0	Out	WRAP_TK	Encrypted TEK and TIK.
30h	127:0	Out	WRAP_IV	IV for key wrap.
40h	255:0	Out	WRAP_MAC	MAC for key wrap.
60h	255:0	Out	POLICY_MAC	Guest policy MAC.

6.8.3 Status Codes

Table 47 enumerates the possible status codes returned by the SEND_START command.

Table 47. SEND_START Status Codes

Return Value	Reason
SUCCESS	Successful completion
INVALID_PLATFORM_STATE	The platform is not in the PSTATE.WORKING state
INVALID_LENGTH	A buffer length is not correct
INVALID_GUEST_STATE	The guest state is not in the GSTATE.RUNNING state
INVALID_GUEST	The guest handle is invalid
INVALID_CERTIFICATE	A certificate chain is not valid
BAD_SIGNATURE	A signature on the certificates is incorrect
INVALID_ADDRESS	A memory region provided contains invalid physical addresses
HWERROR_PLATFORM	A hardware condition has occurred affecting the platform. It is safe to re-allocate parameter buffers.
HWERROR_UNSAFE	A hardware condition has occurred affecting the platform. It is unsafe to re-allocate parameter buffers.

6.9 SEND_UPDATE_DATA

This command is used to export guest memory regions to another platform.

6.9.1 Actions

The platform must be in the PSTATE.WORKING state.

The guest must be in the GSTATE.SUPDATE state.

If the HDR_LEN is too small, the required length is written out to that field and an error is returned. Otherwise, the number of bytes written to the buffer are written into HDR_LEN.

If FLAGS.COMPRESSED is 1, the data pointed to by GUEST_PADDR will first be compressed before encryption and integrity protection. If FLAGS.COMPRESSED is 0, no compression is performed.

A fresh IV is generated and written to the IV field. The data pointed to by GUEST_PADDR is encrypted with the GCTX.TEK. The result is then written to the TRANS_PADDR field. If the input TRANS_LENGTH field is greater than output length of the compressed and encrypted plaintext, the new length is written into the TRANS_LENGTH field. If TRANS_LENGTH is less than the output length of the compressed and encrypted plaintext, an error is returned.

A MAC is computed to integrity protect the data. The MAC is calculated as follows:

HMAC(0x02 || FLAGS || IV || GUEST_LENGTH || TRANS_LENGTH || DATA; GCTX.TIK)

Where "||" represents concatenation, FLAGS is the full 32-bit FLAGS field, and DATA is ciphertext pointed to by TRANS_PADDR. TRANS_LENGTH is the new length written out to the TRANS_LENGTH field. The MAC is written out to the MAC field.

The platform remains in the same state after completion.

The guest remains in the same state after completion.

6.9.2 Parameters

Table 48 specifies the parameters for the SEND_UPDATE_DATA command.

Table 48. SEND_UPDATE_DATA Command Buffer

Byte Offset	Bits	In / Out	Name	Description
00h	31:0	In	HANDLE	Guest handle
04h	31:0	-	-	Reserved. Must be zero.
08h	63:0	In	HDR_PADDR	System physical address of the region containing the packet header.
10h	31:0	In, Out	HDR_LEN	Length of the region containing the packet header in bytes.
14h	31:0	-	-	Reserved. Must be zero
18h	63:0	In	GUEST_PADDR	System physical of the guest memory region. Must be 16 B aligned with the C-bit set.
20h	31:0	In	GUEST_LENGTH	Length of guest memory region. Must be a multiple of 16 B and no more than 16 kB.

Table 48. SEND_UPDATE_DATA Command Buffer (Continued)

Byte Offset	Bits	In / Out	Name	Description
24h	31:0	-	-	
28h	63:0	In	TRANS_PADDR	System physical address of the transport memory buffer.
30h	31:0	In, Out	TRANS_LENGTH	Length of the transport memory buffer.

Table 49. SEND_UPDATE_DATA Packet Header Buffer

Byte Offset	Bits	In / Out	Name	Description
00h	0	Out	FLAGS.COMPRESSED	If set, data is compressed.
	31:1	-	-	Reserved. Must be zero.
04h	127:0	Out	IV	Initialization vector.
14h	255:0	Out	MAC	Integrity protection MAC.

6.9.3 Status Codes

Table 50 enumerates the possible status codes returned by the SEND_UPDATE_DATA command.

Table 50. SEND_UPDATE_DATA Status Codes

Return Value	Reason
SUCCESS	Successful completion.
INVALID_LENGTH	A buffer length is not correct.
INVALID_PLATFORM_STATE	The platform is not in the PSTATE.WORKING state.
INVALID_GUEST_STATE	The guest state is not in the GSTATE.SUPDATE state.
INVALID_PARAM	A parameter is invalid.
INVALID_GUEST	The guest handle is invalid.
INACTIVE	The guest is inactive.
INVALID_ADDRESS	A memory region provided contains invalid physical addresses.
HWERROR_PLATFORM	A hardware condition has occurred affecting the platform. It is safe to re-allocate parameter buffers.
HWERROR_UNSAFE	A hardware condition has occurred affecting the platform. It is unsafe to re-allocate parameter buffers.

6.10 SEND_UPDATE_VMSA

This command is used to export guest VMCB save areas to another platform.

6.10.1 Actions

The platform must be in the PSTATE.WORKING state.

The guest must be in the GSTATE.SUPDATE state.

If the HDR_LEN is too small, the required length is written out to that field and an error is returned. Otherwise, the number of bytes written to the buffer are written into HDR_LEN.

If FLAGS.COMPRESSED is 1, the data pointed to by GUEST_PADDR will first be compressed before encryption and integrity protection. If FLAGS.COMPRESSED is 0, no compression is performed.

A fresh IV is generated and written to the IV field. The data pointed to by GUEST_PADDR is encrypted with the GCTX.TEK. The result is then written to the TRANS_PADDR field. If the input TRANS_LENGTH field is greater than output length of the compressed and encrypted plaintext, the new length is written into the TRANS_LENGTH field. If TRANS_LENGTH is less than the output length of the compressed and encrypted plaintext, an error is returned.

A MAC is computed to integrity protect the data. The MAC is calculated as follows:

HMAC(0x03 || FLAGS || IV || GUEST_LENGTH || TRANS_LENGTH || DATA; GCTX.TIK)

Where "||" represents concatenation, FLAGS is the full 32-bit FLAGS field, and DATA is ciphertext pointed to by TRANS_PADDR. TRANS_LENGTH is the new length written out to the TRANS_LENGTH field. The MAC is written out to the MAC field.

The platform remains in the same state after completion.

The guest remains in the same state after completion.

6.10.2 Parameters

Table 51 and Table 52 specifies the parameters for the SEND_UPDATE_VMSA command.

Table 51. SEND_UPDATE_VMSA Command Buffer

Byte Offset	Bits	In / Out	Name	Description
00h	31:0	In	HANDLE	Guest handle.
04h	31:0	-	-	Reserved. Must be zero.
08h	63:0	In	HDR_PADDR	System physical address of the region containing the packet header.
10h	31:0	In, Out	HDR_LEN	Length of the region containing the packet header in bytes.
14h	31:0	-	-	Reserved. Must be zero.
18h	63:0	In	GUEST_PADDR	System physical of the guest memory region. Must be 16 B aligned with the C-bit set.
20h	31:0	In	GUEST_LENGTH	Length of guest memory region. Must be a multiple of 16 B and no more than 16 kB.
24h	31:0	-	-	
28h	63:0	In	TRANS_PADDR	System physical address of the transport memory buffer.
30h	31:0	In, Out	TRANS_LENGTH	Length of the transport memory buffer.

Table 52. SEND_UPDATE_VMSA Packet Header Buffer

Byte Offset	Bits	In / Out	Name	Description
00h	0	Out	FLAGS.COMPRESSED	If set, data is compressed.
	31:1	-	-	Reserved. Must be zero.
04h	127:0	Out	IV	Initialization vector.
14h	255:0	Out	MAC	Integrity protection MAC.

6.10.3 Status Codes

Table 53 enumerates the possible status codes returned by the SEND_UPDATE_VMSA command.

Table 53. SEND_UPDATE_VMSA Status Codes

Return Value	Reason
SUCCESS	Successful completion.
INVALID_LENGTH	A buffer length is not correct.
INVALID_PLATFORM_STATE	The platform is not in the PSTATE.WORKING state.
INVALID_GUEST_STATE	The guest state is not in the GSTATE.SUPDATE state.
INVALID_PARAM	A parameter is invalid.
INVALID_GUEST	The guest handle is invalid.
UNSUPPORTED	SEV-ES is not configured.
INACTIVE	The guest is inactive.
INVALID_ADDRESS	A memory region provided contains invalid physical addresses.
HWERROR_PLATFORM	A hardware condition has occurred affecting the platform. It is safe to re-allocate parameter buffers.
HWERROR_UNSAFE	A hardware condition has occurred affecting the platform. It is unsafe to re-allocate parameter buffers.

6.11 SEND_FINISH

This command finalizes the send operational flow.

6.11.1 Actions

The platform must be in the PSTATE.WORKING state.

The guest must be in the GSTATE.SUPDATE state.

The following fields of the guest context are zeroed:

- GCTX.TEK
- GCTX.TIK
- GCTX.MS
- GCTX.NONCE

The platform remains in the same state after completion.

The guest transitions to the GSTATE.RUNNING state.

6.11.2 Parameters

Table 54 specify the parameters for the SEND_FINISH command.

Table 54. SEND_FINISH Command Buffer

Byte Offset	Bits	In / Out	Name	Description
00h	31:0	In	HANDLE	Guest handle.

6.11.3 Status Codes

Table 55 enumerates the possible status codes returned by the SEND_FINISH command.

Table 55. SEND_FINISH Status Codes

Return Value	Reason
SUCCESS	Successful completion
INVALID_PLATFORM_STATE	The platform is not in the PSTATE.WORKING state
INVALID_GUEST_STATE	The guest state is not in the GSTATE.SUPDATE state
INVALID_GUEST	The guest handle is invalid
INVALID_ADDRESS	A memory region provided contains invalid physical addresses
HWERROR_PLATFORM	A hardware condition has occurred affecting the platform. It is safe to re-allocate parameter buffers.
HWERROR_UNSAFE	A hardware condition has occurred affecting the platform. It is unsafe to re-allocate parameter buffers.

6.12 RECEIVE_START

This command is used to import a guest from one platform to another. It can be used for restoring a guest from disk, or it can be used to migrate a guest across the network from a sending platform.

6.12.1 Actions

The platform must not be in the PSTATE.UNINIT state.

A new guest context is created and assigned to an available guest handle.

The MAC of GCTX.POLICY is calculated, keyed with TIK. The MAC is compared to the POLICY_MAC field to verify the integrity of the guest policy.

If the HANDLE field is zero, a new VEK is generated for this guest. If the HANDLE field is non-zero, the following checks are performed:

- HANDLE is a valid guest
- GUESTS[HANDLE].POLICY is equal to the POLICY field

- The MAC of the POLICY is valid
- POLICY.NOKS is zero

If the above checks pass, then the VEK from the guest referred to by HANDLE is copied into the new guest context.

The handle of the new guest is written to the HANDLE field.

The master secret is calculated with NONCE and PDH_CERT fields and the PCTX.PDH private key according to the key establishment protocol specified in Chapter 2 on page 22. The transport keys in the WRAPPED_TK field are then unwrapped according to Chapter 2 on page 22 using the WRAP_IV and WRAP_MAC fields as the IV and MAC parameters, respectively.

A version check is performed to ensure that the API version implemented on the platform provides the proper functionality requested by the initiator of the guest. The major API version of this platform must be greater than the guest's POLICY.API_MAJOR field value, or the major API version is equal to POLICY.API_MAJOR, and the minor API version of this platform is greater than or equal to POLICY.API_MINOR. If all of these conditions are not met then an error is returned.

If POLICY.ES is set and the platform is configured with SEV-ES, then SEV-ES is enabled. If POLICY.ES is set and the platform is not configured with SEV-ES, an error is returned. Otherwise, SEV-ES is disabled.

The platform remains in the same state after completion.

The guest transitions to the GSTATE.RUPDATE state.

6.12.2 Parameters

Table 56 and Table 57 specify the parameters for the RECEIVE_START command.

Table 56. RECEIVE_START Command Buffer

Byte Offset	Bits	In / Out	Name	Description
00h	31:0	In, Out	HANDLE	Guest handle
04h	31:0	In	POLICY	Guest policy
08h	63:0	In	PDH_CERT_PADDR	System physical address of the region containing the PDH certificate.
10h	31:0	In	PDH_CERT_LEN	Length of the region containing the PDH certificate in bytes.
14h	31:0	-	-	Reserved. Must be zero
18h	63:0	In	SESSION_PADDR	System physical address of the region containing the session data.
20h	31:0	In	SESSION_LEN	Length of the region containing the session data in bytes.

Table 57. RECEIVE_START Session Data Buffer

Byte Offset	Bits	In / Out	Name	Description
00h	127:0	In	NONCE	Session nonce.
10h	255:0	In	WRAP_TK	Encrypted TEK and TIK.
30h	127:0	In	WRAP_IV	IV for key wrap.
40h	255:0	In	WRAP_MAC	MAC for key wrap.
60h	255:0	In	POLICY_MAC	Guest policy MAC.

6.12.3 Status Codes

Table 58 enumerates the possible status codes returned by the RECEIVE_START command.

Table 58. RECEIVE_START Status Codes

Return Value	Reason
SUCCESS	Successful completion
INVALID_PLATFORM_STATE	The platform is not in the PSTATE.WORKING state
INVALID_LENGTH	A buffer length is not correct
INVALID_GUEST	The guest handle is invalid
INVALID_CERTIFICATE	A certificate chain is not valid
POLICY_FAILURE	A guest policy requirement cannot be honored.
BAD_SIGNATURE	A signature on the certificates is incorrect
BAD_MEASUREMENT	The measurement of the wrapped key or policy is invalid
INVALID_ADDRESS	A memory region provided contains invalid physical addresses
UNSUPPORTED	SEV-ES has not been configured
HWERROR_PLATFORM	A hardware condition has occurred affecting the platform. It is safe to re-allocate parameter buffers.
HWERROR_UNSAFE	A hardware condition has occurred affecting the platform. It is unsafe to re-allocate parameter buffers.

6.13 RECEIVE_UPDATE_DATA

This command is used to import guest memory from a sending platform.

6.13.1 Actions

The platform must be in the PSTATE.WORKING state.

The guest must be in the GSTATE.RUPDATE state.

A MAC is computed to verify the integrity of the data area. The MAC is calculated as follows:

HMAC(0x02 || FLAGS || IV || GUEST_LENGTH || TRANS_LENGTH || DATA; GCTX.TIK)

Where "||" represents concatenation, FLAGS is the full 32-bit FLAGS field, and DATA is ciphertext pointed to by TRANS_PADDR. The MAC is compared against the MAC field which must be equal.

The ciphertext data pointed to by TRANS_PADDR is decrypted with the GCTX.TEK and the IV field. If FLAGS.COMPRESSED is 1, the resulting plaintext data will be decompressed. If FLAGS.COMPRESSED is 0, no compression is performed. The result is then encrypted with GCTX.VEK and written to the memory pointed to by GUEST_PADDR field.

The platform remains in the same state after completion.

The guest remains in the same state after completion.

6.13.2 Parameters

Table 59 and Table 60 specify the parameters for the RECEIVE_UPDATE_DATA command.

Table 59. RECEIVE_UPDATE_DATA Command Buffer

Byte Offset	Bits	In / Out	Name	Description
00h	31:0	In	HANDLE	Guest handle.
04h	31:0	-	-	Reserved. Must be zero.
08h	63:0	In	HDR_PADDR	System physical address of the region containing the packet header.
10h	31:0	In	HDR_LEN	Length of the region containing the packet header in bytes.
14h	31:0	-	-	Reserved. Must be zero.
18h	63:0	In	GUEST_PADDR	System physical of the VMCB save area. Must be 16 B aligned.
20h	31:0	In	GUEST_LENGTH	Length of guest memory region. Must be a multiple of 16 B and no more than 16 kB.
24h	31:0	-	-	Reserved. Must be zero.
28h	63:0	In	TRANS_PADDR	System physical address of the transport memory buffer.
30h	31:0	In	TRANS_LENGTH	Length of the transport memory buffer.

Table 60. RECEIVE_UPDATE_DATA Packet Header Buffer

Byte Offset	Bits	In / Out	Name	Description
00h	0	In	FLAGS.COMPRESSED	If set, data is compressed.
	31:1	-	-	Reserved. Must be zero.
04h	127:0	In	IV	Initialization vector.
14h	255:0	In	MAC	Integrity protection MAC.

6.13.3 Status Codes

Table 61 enumerates the possible status codes returned by the RECEIVE_UPDATE_DATA command.

Table 61. RECEIVE_UPDATE_DATA Status Codes

Return Value	Reason
SUCCESS	Successful completion.
INVALID_PLATFORM_STATE	The platform is not in the PSTATE.WORKING state.
INVALID_LENGTH	A buffer length is not correct.
INVALID_GUEST_STATE	The guest state is not in the GSTATE.RUPDATE state.
INVALID_PARAM	A parameter is invalid.
INVALID_GUEST	The guest handle is invalid.
INACTIVE	The guest is inactive.
INVALID_ADDRESS	A memory region provided contains invalid physical addresses.
BAD_MEASUREMENT	The measurement of the secret is invalid.
HWERROR_PLATFORM	A hardware condition has occurred affecting the platform. It is safe to re-allocate parameter buffers.
HWERROR_UNSAFE	A hardware condition has occurred affecting the platform. It is unsafe to re-allocate parameter buffers.

6.14 RECEIVE_UPDATE_VMSA

This command is used to import a VMCB save area from another platform.

6.14.1 Actions

The platform must be in the PSTATE.WORKING state.

The guest must be in the GSTATE.RUPDATE state.

A MAC is computed to verify the integrity of the VMCB save area. The MAC is calculated as follows:

HMAC(0x03 || FLAGS || IV || GUEST_LENGTH || TRANS_LENGTH || DATA; GCTX.TIK)

Where "||" represents concatenation, FLAGS is the full 32-bit FLAGS field, and DATA is ciphertext pointed to by TRANS_PADDR. The MAC is compared against the MAC field which must be equal.

The ciphertext data pointed to by TRANS_PADDR is decrypted with the GCTX.TEK and the IV field. If FLAGS.COMPRESSED is 1, the resulting plaintext data will be decompressed. If FLAGS.COMPRESSED is 0, no compression is performed. The result is then encrypted with GCTX.VEK and written to the memory pointed to by GUEST_PADDR field.

The platform remains in the same state after completion.

The guest remains in the same state after completion.

6.14.2 Parameters

Table 62 and Table 63 specify the parameters for the RECEIVE_UPDATE_VMSA command.

Table 62. RECEIVE_UPDATE_VMSA Command Buffer

Byte Offset	Bits	In / Out	Name	Description
00h	31:0	In	HANDLE	Guest handle.
04h	31:0	-	-	Reserved. Must be zero.
08h	63:0	In	HDR_PADDR	System physical address of the region containing the packet header.
10h	31:0	In	HDR_LEN	Length of the region containing the packet header in bytes.
14h	31:0	-	-	Reserved. Must be zero.
18h	63:0	In	GUEST_PADDR	System physical of the VMCB save area. Must be 16 B aligned.
20h	31:0	In	GUEST_LENGTH	Length of guest memory region. Must be a multiple of 16 B and no more than 16 kB.
24h	31:0	-	-	Reserved. Must be zero.
28h	63:0	In	TRANS_PADDR	System physical address of the transport memory buffer.
30h	31:0	In	TRANS_LENGTH	Length of the transport memory buffer.

Table 63. RECEIVE_UPDATE_VMSA Packet Header Buffer

Byte Offset	Bits	In / Out	Name	Description
00h	0	In	FLAGS.COMPRESSED	If set, data is compressed.
	31:1	-	-	Reserved. Must be zero.
04h	127:0	In	IV	Initialization vector.
14h	255:0	In	MAC	Integrity protection MAC.

6.14.3 Status Codes

Table 64 enumerates the possible status codes returned by the RECEIVE_UPDATE_VMSA command.

Table 64. RECEIVE_UPDATE_VMSA Status Codes

Return Value	Reason
SUCCESS	Successful completion.
INVALID_PLATFORM_STATE	The platform is not in the PSTATE.WORKING state.
INVALID_LENGTH	A buffer length is not correct.
INVALID_GUEST_STATE	The guest state is not in the GSTATE.RUPDATE state.
INVALID_PARAM	A parameter is invalid.
INVALID_GUEST	The guest handle is invalid.
INACTIVE	The guest is inactive.
UNSUPPORTED	SEV-ES is not configured
INVALID_ADDRESS	A memory region provided contains invalid physical addresses.
BAD_MEASUREMENT	The measurement of the secret is invalid.
HWERROR_PLATFORM	A hardware condition has occurred affecting the platform. It is safe to re-allocate parameter buffers.
HWERROR_UNSAFE	A hardware condition has occurred affecting the platform. It is unsafe to re-allocate parameter buffers.

6.15 RECEIVE_FINISH

This command is used to complete the receive work flow and bring the guest to a state that can be executed.

6.15.1 Actions

The platform must be in the PSTATE.WORKING state.

The guest must be in the GSTATE.RUPDATE state.

The following fields of the guest context are zeroed:

- GCTX.TEK
- GCTX.TIK
- GCTX.MS
- GCTX.NONCE

The platform remains in the same state after completion.

The guest transitions to the GSTATE.RUNNING state.

6.15.2 Parameters

Table 65 specifies the parameters for the RECEIVE_FINISH command.

Table 65. RECEIVE_FINISH Command Buffer

Byte Offset	Bits	In / Out	Name	Description
00h	31:0	In	HANDLE	Guest handle.

6.15.3 Status Codes

Table 66 enumerates the possible status codes returned by the RECEIVE_FINISH command.

Table 66. RECEIVE_FINISH Status Codes

Return Value	Reason
SUCCESS	Successful completion.
INVALID_PLATFORM_STATE	The platform is not in the PSTATE.WORKING state.
INVALID_LENGTH	A buffer length is not correct.
INVALID_GUEST_STATE	The guest state is not in the GSTATE.RUPDATE state.
INVALID_GUEST	The guest handle is invalid.
INVALID_ADDRESS	A memory region provided contains invalid physical addresses.
HWERROR_PLATFORM	A hardware condition has occurred affecting the platform. It is safe to re-allocate parameter buffers.
HWERROR_UNSAFE	A hardware condition has occurred affecting the platform. It is unsafe to re-allocate parameter buffers.

6.16 GUEST_STATUS

This command is used to retrieve status information about an SEV-enabled guest.

6.16.1 Actions

The platform must be in the PSTATE.INIT or PSTATE.WORKING states.

The guest may be in any state.

If the HANDLE field is invalid, the STATE field is set to 0h and all other parameters are untouched.

The platform remains in the same state after completion.

The guest remains in the same state after completion.

6.16.2 Parameters

Table 67 specify the parameters for the GUEST_STATUS command.

Table 67. GUEST_STATUS Command Buffer

Byte Offset	Bits	In / Out	Name	Description
00h	31:0	In	HANDLE	Guest handle.
04h	31:0	Out	POLICY	Guest policy.
08h	31:0	Out	ASID	Current ASID. If not active, set to 0h.
0Ch	7:0	Out	STATE	Current guest state. See Table 27.

6.16.3 Status Codes

Table 68 enumerates the possible status codes returned by the DEACTIVATE command.

Table 68. GUEST_STATUS Status Codes

Return Value	Reason
SUCCESS	Successful completion.
INVALID_PLATFORM_STATE	The platform is not in the PSTATE.WORKING state.
INVALID_ADDRESS	A memory region provided contains invalid physical addresses.
HWERROR_PLATFORM	A hardware condition has occurred affecting the platform. It is safe to re-allocate parameter buffers.
HWERROR_UNSAFE	A hardware condition has occurred affecting the platform. It is unsafe to re-allocate parameter buffers.

6.17 ACTIVATE

This command is used to inform the firmware that the guest is bound to a particular ASID. The firmware then loads the guest's VEK into the memory controller at the key slot for that ASID.

6.17.1 Actions

The platform must be in the PSTATE.WORKING state.

The guest may be in any state.

The guest must be inactive. The ASID parameter must not be zero and must be a valid SEV ASID. The ASID must not be currently used by another guest.

If the guest is SEV-ES enabled, then the ASID must be at least 1h and at most (MIN_SEV_ASID-1). If the guest is not SEV-ES enabled, then the ASID must be at least MIN_SEV_ASID and at most the maximum SEV ASID available. The MIN_SEV_ASID value is discovered by CPUID Fn8000_001F[EDX]. The maximum SEV ASID available is discovered by CPUID Fn8000_001F[ECX].

DF_FLUSH must be executed since the last DEACTIVATE command was issued.

The VEK of the guest identified by HANDLE is loaded into the memory controller in the slot identified by ASID. The ASID is then marked valid on all cores.

The platform remains in the same state after completion.

The guest remains in the same state after completion..

6.17.2 Parameters

Table 69 specifies the parameters for the ACTIVATE command.

Table 69. ACTIVATE Command Buffer

Byte Offset	Bits	In / Out	Name	Description
00h	31:0	In	HANDLE	Guest handle.
04h	31:0	In	ASID	ASID to activate the guest with.

6.17.3 Status Codes

Table 70 enumerates the possible status codes returned by the ACTIVATE command.

Table 70. ACTIVATE Status Codes

Return Value	Reason
SUCCESS	Successful completion.
INVALID_PLATFORM_STATE	The platform is not in the working state.
ACTIVE	The guest is currently active.
INVALID_GUEST	The guest handle is invalid.
ASID_OWNED	The ASID is already in use by another guest.
INVALID_ASID	The ASID is invalid.
INVALID_ADDRESS	A memory region provided contains invalid physical addresses.
DFFLUSH_REQUIRED	A DF_FLUSH has not be invoked since the last DEACTIVATE invocation.
HWERROR_PLATFORM	A hardware condition has occurred affecting the platform. It is safe to re-allocate parameter buffers.
HWERROR_UNSAFE	A hardware condition has occurred affecting the platform. It is unsafe to re-allocate parameter buffers.

6.18 DEACTIVATE

This command is used to dissociate the guest from its current ASID. The firmware will uninstall the guest's key from the memory controller.

6.18.1 Actions

The platform must be in the PSTATE.WORKING state.

The guest may be in any state.

The firmware uninstalls the guest's key from the memory controller and records that a DF_FLUSH is required for this ASID. The ASID is marked invalid on all cores.

The platform remains in the same state after completion.

The guest remains in the same state after completion.

6.18.2 Parameters

Table 71 specifies the parameters for the DEACTIVATE command.

Table 71. DEACTIVATE Command Buffer

Byte Offset	Bits	In / Out	Name	Description
00h	31:0	In	HANDLE	Guest handle.

6.18.3 Status Codes

Table 72 enumerates the possible status codes returned by the DEACTIVATE command.

Table 72. DEACTIVATE Status Codes

Return Value	Reason
SUCCESS	Successful completion.
INVALID_PLATFORM_STATE	The platform is not in the PSTATE.WORKING state.
INVALID_ASID	The ASID is invalid.
INVALID_GUEST	The guest handle is invalid.
INVALID_ADDRESS	A memory region provided contains invalid physical addresses.
HWERROR_PLATFORM	A hardware condition has occurred affecting the platform. It is safe to re-allocate parameter buffers.
HWERROR_UNSAFE	A hardware condition has occurred affecting the platform. It is unsafe to re-allocate parameter buffers.

6.19 DF_FLUSH

The x86 system software invokes this command after deactivating one or more guests. The x86 system software must execute a WBINVD on the hardware threads that the previous guest was active on before invoking the DF_FLUSH command.

6.19.1 Actions

The platform must be in the PSTATE.INIT or PSTATE.WORKING states. Otherwise, an error is returned.

Each core must have executed a WBINVD instruction since the last DEACTIVATE command was invoked.

The data fabric write buffers are flushed for each core. The firmware also records that a flush has been performed for all ASIDs.

The platform remains in the same state after completion.

6.19.2 Parameters

None. The CmdBuf_Lo and CmdBuf_Hi mailbox registers are ignored.

6.19.3 Status Codes

Table 73 enumerates the possible status codes returned by the DF_FLUSH command.

Table 73. DF_FLUSH Command Status Codes

Return Value	Reason
SUCCESS	Successful completion
INVALID_PLATFORM_STATE	The platform is not in the PSTAET.INIT or PSTATE.WORKING states
WBINVD_REQUIRED	WBINVD has not been executed
HWERROR_PLATFORM	A hardware condition has occurred affecting the platform. It is safe to re-allocate parameter buffers.
HWERROR_UNSAFE	A hardware condition has occurred affecting the platform. It is unsafe to re-allocate parameter buffers.

6.20 DECOMMISSION

The hypervisor no longer intends to run the guest. Invoking this command deletes all guest context for this guest. Upon successful completion of this command, HANDLE is no longer a valid guest handle. Guests that shared their VEK with this guest are not affected.

6.20.1 Actions

The platform must be in the PSTATE.WORKING state.

The guest handle must be valid. The guest may be in any state.

The guest must not be active. The hypervisor must invoke DEACTIVATE for the guest before invoking DECOMMISSION.

All guest context is securely deleted from firmware memory. After completion, the guest handle will not be valid.

The platform transitions to the PSTATE.INIT state if PCTX.GUEST_COUNT is zero. Otherwise, the platform remains in the PSTATE.WORKING state.

6.20.2 Parameters

Table 74 specifies the parameters for the DECOMMISSION command.

Table 74. DECOMMISSION Command Buffer

Byte Offset	Bits		In / Out	Name	Description
00h	31:0		In	HANDLE	Guest handle.

6.20.3 Status Codes

Table 75 enumerates the possible status codes returned by the DECOMMISSION command.

Table 75. DECOMMISSION Status Codes

Return Value	Reason
SUCCESS	Successful completion.
INVALID_PLATFORM_STATE	The platform is not in the PSTATE.WORKING state.
ACTIVE	The guest is currently active.
INVALID_GUEST	The guest handle is invalid.
INVALID_ADDRESS	A memory region provided contains invalid physical addresses.
HWERROR_PLATFORM	A hardware condition has occurred affecting the platform. It is safe to re-allocate parameter buffers.
HWERROR_UNSAFE	A hardware condition has occurred affecting the platform. It is unsafe to re-allocate parameter buffers.

Chapter 7 Debugging API

The debugging API provides a simple interface to decrypt and encrypt memory with a guest's VEK. This allows developers of guest kernels and hypervisor to troubleshoot bugs. The commands in this chapter can be (and, in production environments, should be) disabled via the Guest Policy bit NODBG (see Table 2. Guest Policy Structure) established in LAUNCH_START.

7.1 DBG_DECRYPT

This command enables developers of hypervisors and guest kernels to access encrypted memory.

7.1.1 Actions

The guest policy must allow debugging.

The contents of the source region starting at SRC_PADDR and extending LENGTH bytes are decrypted using GCTX.VEK and saved into the destination memory region starting at DST_PADDR and extending LENGTH bytes.

The guest and platform states are unaffected.

7.1.2 Parameters

Table 76 specifies the parameters for the DBG_DECRYPT command.

Table 76. DBG_DECRYPT Command Buffer

Byte Offset	Bits	In / Out	Name	Description
00h	31:0	In	HANDLE	Guest handle.
04h	31:0	-	-	Reserved. Must be zero.
08h	63:0	In	SRC_PADDR	System physical address of data to decrypt. Must be 16 B aligned.
10h	63:0	In	DST_PADDR	System physical address of destination. Must be 16 B aligned.
18h	31:0	In	LENGTH	Length of regions. Must be 16 B aligned.

7.1.3 Status Codes

Table 77 enumerates the possible status codes returned by the DBG_DECRYPT command.

Table 77. DBG_DECRYPT Status Codes

Return Value	Reason
SUCCESS	Successful completion.
INVALID_PLATFORM_STATE	The platform is not in the PSTATE.WORKING state.
INVALID_LENGTH	A buffer length is not correct.
INVALID_GUEST	The guest handle is invalid.
INACTIVE	The guest is inactive.
INVALID_ADDRESS	A memory region provided contains invalid physical addresses.
POLICY_FAILURE	The policy disallows debugging.
HWERROR_PLATFORM	A hardware condition has occurred affecting the platform. It is safe to re-allocate parameter buffers.
HWERROR_UNSAFE	A hardware condition has occurred affecting the platform. It is unsafe to re-allocate parameter buffers.

7.2 DBG_ENCRYPT

This command allows a developer to encrypt memory for debugging purposes.

7.2.1 Actions

The guest policy must allow debugging.

The contents of the source region, starting at SRC_PADDR and extending LENGTH bytes, are encrypted using GCTX.VEK and saved into the destination memory region, starting at DST_PADDR and extending LENGTH bytes.

The guest and platform states are unaffected.

7.2.2 Parameters

Table 78 specifies the parameters for the DBG_ENCRYPT command.

Table 78. DBG_ENCRYPT Command Buffer

Byte Offset	Bits	In / Out	Name	Description
00h	31:0	In	HANDLE	Guest handle.
04h	31:0	-	-	Reserved. Must be zero.
08h	63:0	In	SRC_PADDR	System physical address of data to encrypt. Must be 16 B aligned.
10h	63:0	In	DST_PADDR	System physical address of destination. Must be 16 B aligned.
18h	31:0	In	LENGTH	Length of regions. Must be 16 B aligned.

7.2.3 Status Codes

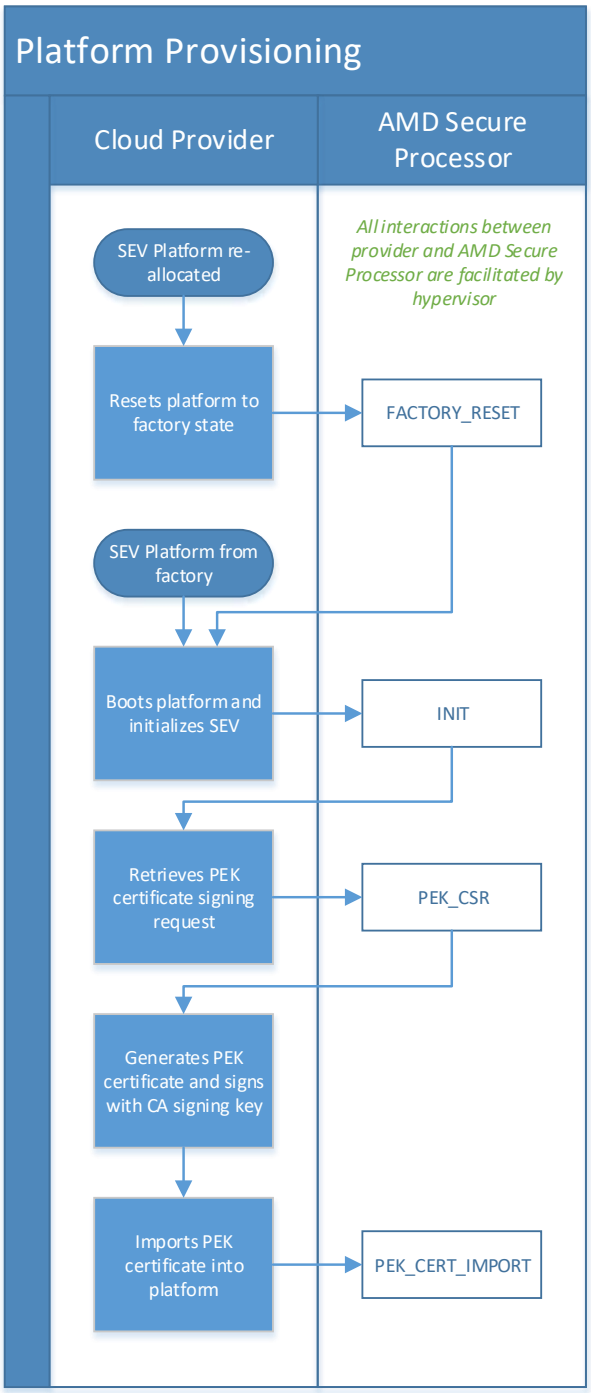
Table 79 enumerates the possible status codes returned by the DBG_ENCRYPT command.

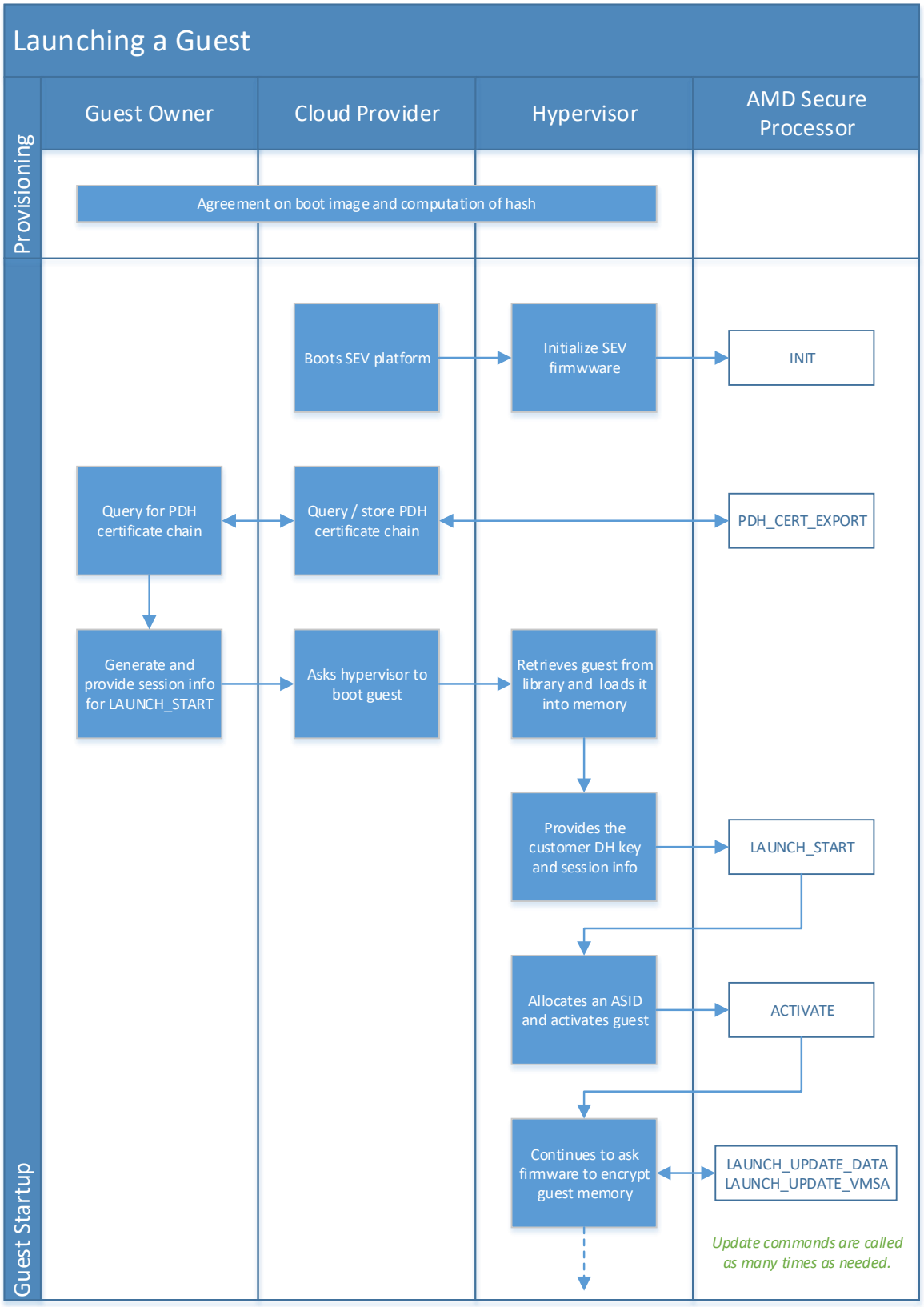
Table 79. DBG_ENCRYPT Status Codes

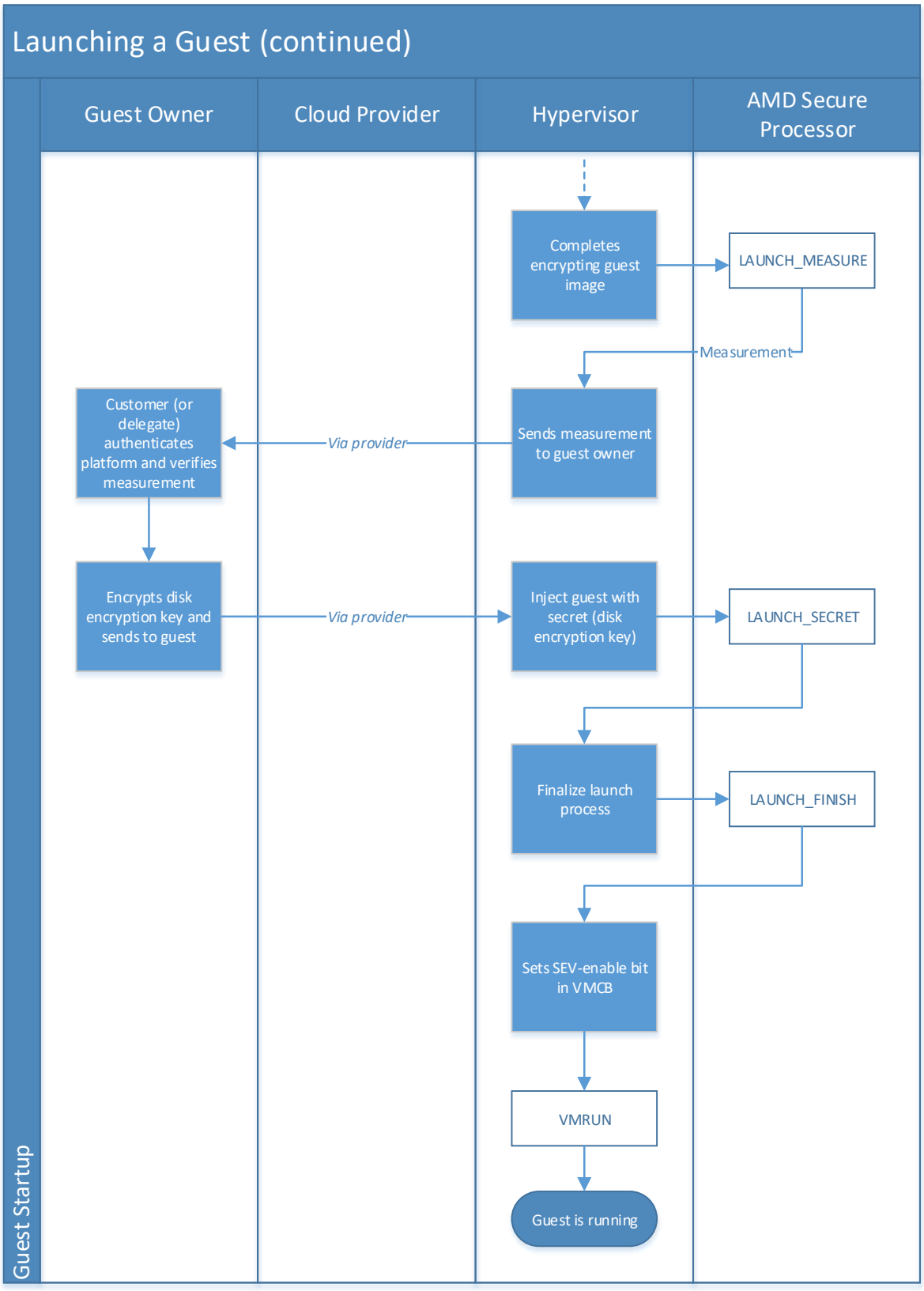
Return Value	Reason
SUCCESS	Successful completion.
INVALID_PLATFORM_STATE	The platform is not in the PSTATE.WORKING state.
INVALID_LENGTH	A buffer length is not correct.
INVALID_GUEST	The guest handle is invalid.
INACTIVE	The guest is inactive.
INVALID_ADDRESS	A memory region provided contains invalid physical addresses.
POLICY_FAILURE	The policy disallows debugging.
HWERROR_PLATFORM	A hardware condition has occurred affecting the platform. It is safe to re-allocate parameter buffers.
HWERROR_UNSAFE	A hardware condition has occurred affecting the platform. It is unsafe to re-allocate parameter buffers.

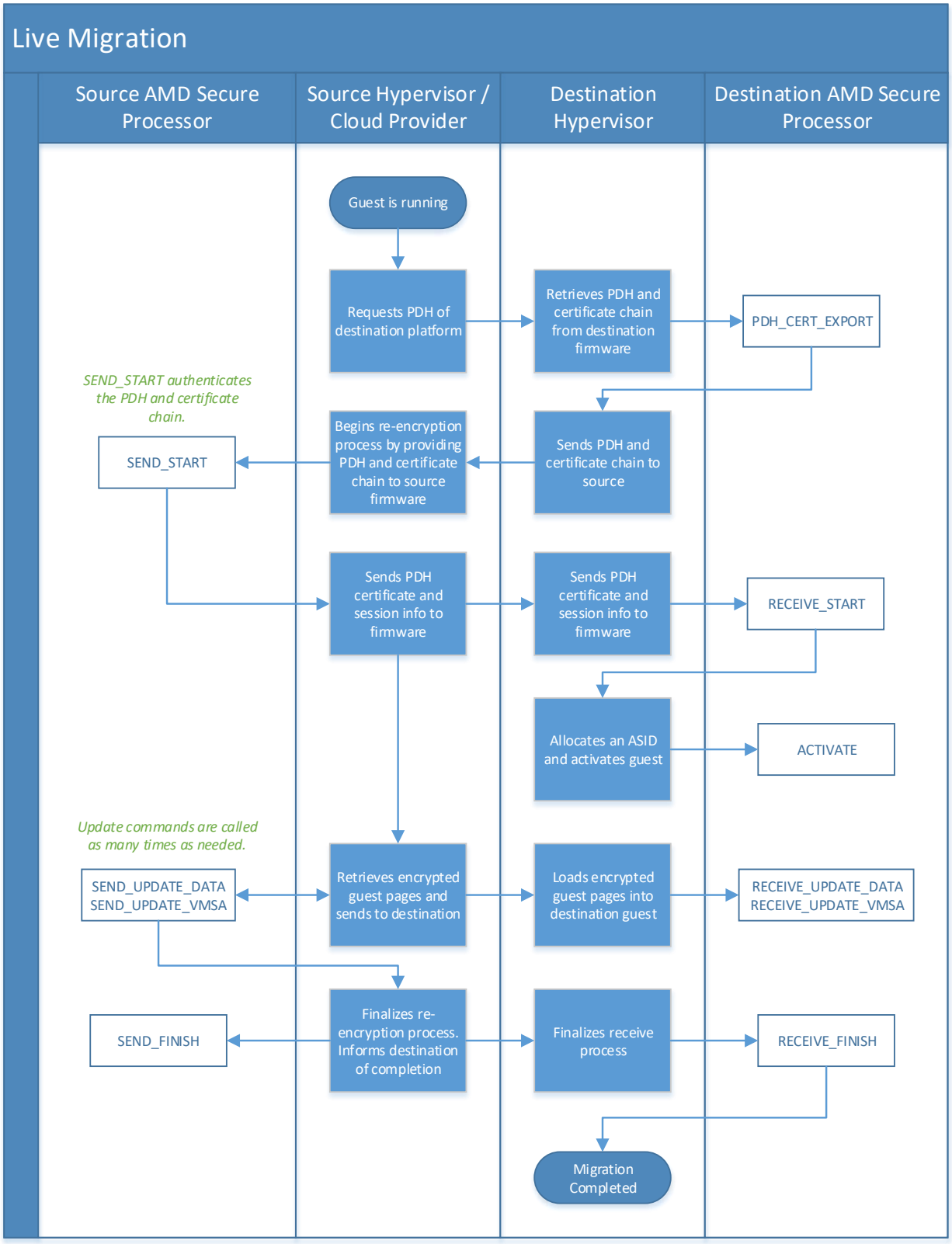
Appendix A Usage Flows

The following flow charts are provided to illustrate the how the usage of the SEV API might be implemented. Note that these are only examples and there may be other implementation strategies.




Launching a Guest
Guest Owner
Cloud Provider
Hypervisor
AMD Secure Processor
Provisioning
Agreement on boot image and computation of hash
Guest Startup
Boots SEV platform
Initialize SEV firmware
INIT
Query for PDH certificate chain
Query / store PDH certificate chain
PDH_CERT_EXPORT
Generate and provide session info for LAUNCH_START
Asks hypervisor to boot guest
Retrieves guest from library and loads it into memory
Provides the customer DH key and session info
LAUNCH_START
Allocates an ASID and activates guest
ACTIVATE
Continues to ask firmware to encrypt guest memory
LAUNCH_UPDATE_DATA
LAUNCH_UPDATE_VMSA
Update commands are called as many times as needed.


Launching a Guest (continued)
Guest Owner
Cloud Provider
Hypervisor
AMD Secure Processor
Completes encrypting guest image
LAUNCH_MEASURE
Measurement
Customer (or delegate) authenticates platform and verifies measurement
Via provider
Sends measurement to guest owner
Encrypts disk encryption key and sends to guest
Via provider
Inject guest with secret (disk encryption key)
LAUNCH_SECRET
Finalize launch process
LAUNCH_FINISH
Sets SEV-enable bit in VMCB
VMRUN
Guest is running
Guest Startup


Live Migration
Source AMD Secure Processor
Source Hypervisor / Cloud Provider
Destination Hypervisor
Destination AMD Secure Processor
Guest is running
Requests PDH of destination platform
Retrieves PDH and certificate chain from destination firmware
PDH_CERT_EXPORT
SEND_START authenticates the PDH and certificate chain.
SEND_START
Begins re-encryption process by providing PDH and certificate chain to source firmware
Sends PDH and certificate chain to source
Sends PDH certificate and session info to firmware
Sends PDH certificate and session info to firmware
RECEIVE_START
Allocates an ASID and activates guest
ACTIVATE
Update commands are called as many times as needed.
SEND_UPDATE_DATA
SEND_UPDATE_VMSA
Retrieves encrypted guest pages and sends to destination
Loads encrypted guest pages into destination guest
RECEIVE_UPDATE_DATA
RECEIVE_UPDATE_VMSA
SEND_FINISH
Finalizes re-encryption process. Informs destination of completion
Finalizes receive process
RECEIVE_FINISH
Migration Completed

Appendix B AMD Certificate Authority Certificates

AMD maintains a certificate authority to authenticate AMD hardware and software for a number of applications. The root of trust of the certificate authority is the AMD Root Signing Key (ARK). This key then signs the AMD SEV Signing Key (ASK), which is an intermediate certificate authority specifically used for SEV related authentication.

B.1 Certificate Format

Table 80 specifies the format of the certificates for the ASK and ARK. This version of the API supports version 01h of the certificate format. Table 81 enumerates the valid key usage values for the KEY_USAGE field.

Table 80. AMD Signing Key Certificate Format

Byte Offset	Bits	Name	Description
00h	31:0	VERSION	Certificate format version. The API expects a 1.
04h	127:0	KEY_ID	The unique ID for this key.
14h	127:0	CERTIFYING_ID	The unique ID for the key that signed this certificate. If this certificate is self-signed, then this field equals the KEY_ID field.
24h	31:0	KEY_USAGE	Usage of the key. See Table 81.
28h	127:0	-	Reserved. Set to zero.
38h	31:0	PUBEXP_SIZE	Size of the public exponent in bits. Must be 2048 or 4096.
3Ch	31:0	MODULUS_SIZE	Size of the public modulus in bits. Must be 2048 or 4096.
40h	2047:0 or 4095:0	PUBEXP	Public exponent of this key. The size of this field in bits is equal to PUBEXP_SIZE.
-	2047:0 or 4095:0	MODULUS	Public modulus of this key. The size of this field in bits is equal to MODULUS_SIZE.
-	2047:0 or 4095:0	SIGNATURE	Signature of this key. The size of this field in bits is equal to MODULUS_SIZE in.

Table 81. Key Usage Encoding

Key Usage	Description
00h	AMD Root Signing Key.
13h	AMD SEV Signing Key.

B.2 Certificate Signature

The ARK and ASK certificates both carry RSASSA-PSS signatures using SHA-256 as the digest algorithm.

B.3 Certificate Validation

The following procedure validates an AMD SEV Signing Key certificate:

1. Verify that the ASK VERSION field is a version supported by this API version (1).
2. Verify that the ASK KEY_USAGE field is equal to the ASK key usage encoding.
3. Verify that the ASK PUBEXP_SIZE field is equal to 4096 or 2048.
4. Verify that the ASK MOD_SIZE field is equal to 4096 or 2048.
5. Verify that the ARK VERSION field is a version supported by this API version (1).
6. Verify that the ARK KEY_USAGE field is equal to the ARK key usage encoding.
7. Verify that the ARK PUBEXP_SIZE field is equal to 4096 or 2048.
8. Verify that the ARK MOD_SIZE field is equal to 4096 or 2048.
9. Verify that the ARK KEY_ID field is equal to the ASK CERTIFYING_ID field.
10. Verify that the ASK SIGNATURE field is a valid signature by the ARK.
11. Verify that the ARK SIGNATURE field is a valid signature by the ARK.

If any of the above fail, the certificate is invalid.

Appendix C SEV Certificates

The PEK, CEK, OCA, and PDH key pairs all have certificates used to authenticate the platform. The certificates for the PEK, CEK, OCA, and PDH are distinct from the certificate used within the AMD certificate authority described in Appendix B.

C.1 Certificate Format

An SEV certificate consists of a certificate version, public key, and zero, one, or two signatures. Table 76 specifies the layout of a SEV certificate.

Table 82. SEV Certificate Format

Byte Offset	Bits	Name	Description
000h	31:0	VERSION	Certificate version, set to 01h.
004h	7:0	API_MAJOR	If PEK, set to API minor version Otherwise, zero.
005h	7:0	API_MINOR	If PEK, set to API minor version Otherwise, zero.
006h	7:0	-	Reserved. Set to zero.
007h	7:0	-	Reserved. Set to zero.
008h	31:0	PUBKEY_USAGE	Public key usage
00Ch	31:0	PUBKEY_ALGO	Public key algorithm
010h – 413h	-	PUBKEY	Public key
414h	31:0	SIG1_USAGE	Key usage of SIG1 signing key
418h	31:0	SIG1_ALGO	First signature algorithm
41Ch – 61Bh	-	SIG1	First signature
61Ch	31:0	SIG2_USAGE	Key usage of SIG2 signing key
620h	31:0	SIG2_ALGO	Second signature algorithm
624h – 823h	-	SIG2	Second signature

Table 83. USAGE Enumeration (All other encodings are reserved)

Value	Enumeration
0000h	ARK
0013h	ASK
1000h	*Invalid*
1001h	OCA
1002h	PEK
1003h	PDH
1004h	CEK

Table 84. ALGO Enumeration (All other encodings are reserved)

Value	Enumeration
0h	Invalid
1h	RSA
2h	ECDSA
3h	ECDH

The PUBKEY field contains the public key represented by this certificate. The format of the PUBKEY field is determined by the PUBKEY_ALGO field. The PUBKEY_ALGO field must be one of the valid algorithms enumerated in Table 83 on page 92. See Section C.2 for the format of the public key for each algorithm.

The PUBKEY_USAGE field specifies the SEV specific usage for the public key represented by this certificate. Table 83 on page 92 enumerates the possible usage identifiers.

The certificate may have zero, one, or two signatures. SIG1_USAGE and SIG2_USAGE describe the key usage for the certifying key that signed the certificate. If SIG1_USAGE is 1000h, SIG1 is not present and the SIG1_ALGO and SIG1 fields are ignored. If SIG2_USAGE is 1000h, SIG2 is not present and the SIG2_ALGO and SIG2 fields are ignored.

The SIG1 and SIG2 fields are formatted according to the SIG1_ALGO and SIG2_ALGO fields, respectively. SIG1_ALGO and SIG2_ALGO must each specify a signing key algorithm from Table 84. See Section C.4, on page 95, for the format of each signature algorithm.

C.2 Elliptic Curve Enumeration

Table 85. CURVE Enumeration (All other encodings are reserved)

Value	Enumeration
0h	Invalid
1h	P256
2h	P384

The above table describes elliptic curves used by the SEV firmware. Note that the NIST P-256 curve is not currently supported but reserved for future usage.

C.3 Public Key Formats

The following subsections describe the public key formats for the SEV certificates.

C.3.1 RSA Public Key

The ALGO.RSA public key format is specified in Table 86. This format supports RSA keys up to 4096 bits in size.

Table 86. RSA Public Key

Byte Offset	Bits	Name	Description
000h	31:0	MODULUS_SIZE	Size of modulus in bits.
004h	4095:0	PUBEXP	Public exponent.
204h	4095:0	MODULUS	Modulus.

C.3.2 ECDSA Public Key

The ALGO.ECDSA public key format is specified in Table 87. The CURVE field specifies which elliptic curve that the public key is defined on. The supported curves are defined in Section C.2 on page 93.

Table 87. ECDSA Public Key

Byte Offset	Bits	Name	Description
000h	31:0	CURVE	Curve ID.
004h	575:0	QX	x component of the public point Q.
04Ch	575:0	QY	y component of the public point Q.
094h – 403h	-	-	Reserved. Must be zero.

C.3.3 ECDH Public Key

The ALGO.ECDH public key format is specified in Table 82. The CURVE field specifies which elliptic curve that the public key is defined on. The supported curves are defined in Section C.2 on page 89.

Table 88. ECDH Public Key

Byte Offset	Bits	Name	Description
000h	31:0	CURVE	Curve ID.
004h	575:0	QX	x component of the public point Q.
04Ch	575:0	QY	y component of the public point Q.
094h – 403h	-	-	Reserved. Must be zero.

C.4 Signature Formats

The following subsections describe the signature formats for the SEV certificates.

C.4.1 RSA Signature

The ALGO.RSA signature format is specified in Table 89. This format supports signatures by RSA keys up to 4096 bits in size.

Table 89. RSA Signature

Byte Offset	Bits	Name	Description
000h – 1FFh	4095:0	S	Signature.

C.4.2 ECDSA Signature

The ALGO.ECDSA signature format is specified in Table 84.

Table 90. ECDSA Signature

Byte Offset	Bits	Name	Description
000h – 047h	575:0	R	R component of the signature.
048h – 08Fh	575:0	S	S component of the signature.
090h – 1FFh	-	-	Reserved. Must be zero.

C.5 Certificate Validation

The following procedure validates an SEV certificate chain:

1. PDH certificate
   a. Verify that the API_MAJOR field is equal to this API major version
   b. Verify that the API_MINOR field is less than or equal to this API minor version
   c. Verify that the VERSION field is supported by this API version
   d. Verify that the PUBKEY_USAGE field is equal to the PDH key usage encoding
   e. Verify that SIG1_USAGE field is equal to the PEK key usage encoding
   f. Verify that SIG1_ALGO field is equal to the PUBKEY_ALGO field of the PEK certificate
   g. Verify that the SIG1 field is a valid signature by the PEK certificate's public key
2. PEK certificate
   a. Verify that the API_MAJOR field is equal to this API major version

b. Verify that the API_MINOR field is less than or equal to this API minor version
c. Verify that the VERSION field is supported by this API version
d. Verify that the PUBKEY_USAGE field is equal to the PEK key usage encoding
e. Verify that SIG1_USAGE field is equal to the CEK key usage encoding
f. Verify that SIG1_ALGO field is equal to the PUBKEY_ALGO field of the CEK certificate
g. Verify that the SIG1 field is a valid signature by the CEK certificate's public key
h. Verify that SIG2_USAGE field is equal to the OCA key usage encoding
i. Verify that SIG2_ALGO field is equal to the PUBKEY_ALGO field of the OCA certificate
j. Verify that the SIG2 field is a valid signature by the OCA certificate's public key
k. Note: SIG1 and SIG2 can be swapped. That is, SIG1 could be the OCA certificate and SIG2 could be the CEK certificate.

3. OCA certificate
   a. Verify that the API_MAJOR field is equal to this API major version
   b. Verify that the API_MINOR field is less than or equal to this API minor version
   c. Verify that the VERSION field is supported by this API version
   d. Verify that the PUBKEY_USAGE field is equal to the OCA key usage encoding
   e. Verify that SIG1_USAGE field is equal to the PEK key usage encoding
   f. Verify that SIG1_ALGO field is equal to the PUBKEY_ALGO field
   g. Verify that the SIG1 field is a valid self signature
4. CEK certificate
   a. Verify that the API_MAJOR field is equal to this API major version
   b. Verify that the API_MINOR field is less than or equal to this API minor version
   c. Verify that the VERSION field is supported by this API version
   d. Verify that the PUBKEY_USAGE field is equal to the CEK key usage encoding
   e. Verify that SIG1_USAGE field is equal to the ASK key usage encoding
   f. Verify that SIG1_ALGO field is equal to the PUBKEY_ALGO field of the ASK certificate
   g. Verify that the SIG1 field is a valid signature by the ASK certificate's public key
5. ASK certificate – see Section B
6. ARK certificate – see Section B

If any of the above fail, the certificate is invalid